Non-Commercial Spruce Release

PRACTITIONERS' GUIDE

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Last updated: Fall 2025
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COVER PHOTO: A restoration crew hikes to spruce release sites. © Geneva Brown

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Introduction

Purpose of this guide

This guide is designed to assist ecological restoration practitioners and forestry professionals in implementing non-commercial red spruce release for restoration in the central and southern Appalachians. Forestry prescriptions to accelerate the growth of red spruce to the canopy, referred to in this guide as "spruce release," are a specialized suite of practices. Spruce release practices can be highly variable depending on site conditions, with many in-field nuanced decisions that can impact long-term restoration outcomes. The purpose of this guide is to outline methodologies, best practices and lessons learned for implementing spruce release for a range of ecological outcomes. As spruce restoration continues to be elevated as a priority among federal and state land managers, we hope this guide can support expanding the spruce restoration workforce across the Appalachians.

What this guide is not

This guide does not outline silvicultural prescriptions and is not necessarily relevant to other ecosystems. Guide users should consult peer-reviewed literature and local experts to better understand these rare ecosystems. Users of this guide are expected to have a basic understanding of spruce ecology, late successional forest dynamics, and principles of restoration ecology. This guide is intended to be used thoughtfully by restoration practitioners, with an understanding of the science that supports spruce release outcomes, and respect for the ecosystems we seek to restore.

Other resources to consider

Partners from the Central and Southern Appalachian Spruce Restoration Initiatives (CASRI and SASRI), which are interdisciplinary informal collaboratives of state and federal land managers, nonprofits, and research institutions, contributed to a book for land managers titled *Ecology and Restoration of Red Spruce*

Ecosystems of the Central and Southern Appalachians (Brown et al., 2026). This open-access online book is the culmination of decades of collaboration among dozens of dedicated conservation managers, naturalists, and restoration practitioners with expertise in spruce ecology and restoration. This guide is designed as a companion piece to Brown et al. We recommend that restoration practitioners consult Chapter 5: Ecosystem Dynamics, and Chapter 9: Ecological Restoration and Adaptive Management before implementing non-commercial spruce release.

Disclaimers

This is a living guide and is subject to change as science and restoration practices advance. This guide was developed based on experience gained implementing non-commercial spruce release on the Monongahela National Forest in West Virginia, dating back to 2014. The practices presented herein are derived from work on a small subset of red spruce forest community types, predominantly Red Spruce–Hemlock–Beech forests and Red Spruce–Yellow Birch forests in West Virginia, and are not necessarily applicable in all community types (see Brown et al. 2026, Chapter 4: Plant Communities). In addition, restoration practitioners should be well versed in the local land management issues and ecological sensitivities of their project areas and apply our guidance in a manner that elevates and respects local knowledge, concerns, and ecologies.

The authors

Will Evans and Noah Reed are the Ecological Restoration Manager and Ecological Restoration Coordinator, respectively, for The Nature Conservancy in West Virginia. They have been working on non-commercial spruce release on the Monongahela National Forest for a combined 8+ years. They have both managed multiple non-commercial release crews and have released over 2,000 acres of treatment units. They have advised partners on non-commercial spruce release projects in Pennsylvania, West Virginia, Virginia, and North Carolina on private, state, and federally owned lands. This guide represents the culmination of their lessons learned and TNC West Virginia's non-commercial spruce release work. They are deeply indebted to Ben Rhodes, who developed the initial practices for red spruce release while working for TNC from 2013 to 2020. Their work is an extension of Rhodes' time working in the red spruce forests of West Virginia.

Special thanks to the following colleagues for their review and commentary during the creation of this guide:

- Jim Connolly, USFS, Monongahela National Forest
- Jarrett Craven, USFS, Monongahela National Forest
- Rachael Dickson, USFS, Pisgah National Forest
- Mike Elza, USFS, Monongahela National Forest
- Caity Embly, TNC Maryland
- Christian Gehman, Appalachian Conservation Corps
- Tal Jacobs, TNC Virginia
- Deborah Landau, TNC Maryland
- Jordan Luff, TNC North Carolina
- Katy Shallows, TNC Appalachians
- Rob Warmath, USFS, Nantahala National Forest
- Marcus Wood, USFS, Pisgah National Forest
- Chris Zimmerman, TNC New York

Spruce seedlings taking root on a tip-up mound, a common germination medium for spruce in late successional forests. © Will Evans/TNC

Background Information

Spruce ecology

Red spruce is a late successional tree species evolved to thrive in an uneven-aged, highly complex forest. While spruce grow slowly compared to hardwoods, they are highly tolerant of poor site conditions, including acidic and/or rocky soils, harsh climates, and deep shade. Regeneration in spruce-dominant forests is driven by small canopy gaps. Given past land use, including unsustainable industrial logging from the late 1800s to early 1900s, most of today's spruce-northern hardwoods forests in Central and Southern Appalachia are even-aged, roughly 80 to 120 years old, and dominated by faster growing hardwoods like red maple, yellow birch, and black cherry. Industrial-scale clear cutting reset forest succession in Appalachia and led to a dramatic decline in the range of red spruce. In these even-aged stands, small canopy gaps are uncommon, and spruce often remain suppressed in the understory. Spruce are ecosystem engineers that shift forest dynamics to favor more spruce regeneration. Spruce shade forest floors, inhibiting germination of shade-intolerant hardwoods, reducing competition, and enhancing the potential of multiple cohorts of spruce regeneration. Spruce needles build organic matter in soils, creating a sponge-like effect during heavy rain. Thicker organic soils absorb more water, storing it underground where it remains cooler and releases more slowly into streams than in hardwood forests. Absorbent spruce soils contribute to cold-water fishery health.

For more information on the evolutionary history of spruce and spruce forest dynamics, consult Chapter 1: History and Biogeography, Chapter 2: The Biology of Red Spruce, and Chapter 5: Ecosystem Dynamics in the Ecology and *Restoration of Red Spruce Ecosystems of the Central and Southern Appalachians* (Brown et al. 2026).

Why release spruce?

When spruce are suppressed, they are unable to influence forest dynamics and fail to provide the ecological functions and services that spruce stands create. In even-aged forests like those previously described, active management is needed to reintroduce small canopy disturbances, advance forest succession, and improve stand heterogeneity to mimic late successional stands. The non-commercial release methods described throughout this guide are designed to mimic natural canopy disturbance in a way that accelerates natural successional pathways, increases stand heterogeneity and health, and maintains reference or desired plant community diversity.

What is Non-commercial red spruce release?

Non-commercial red spruce release is the process of identifying patches of healthy and vigorous red spruce trees suppressed by hardwood competition, culling the competing hardwoods, thereby increasing light reaching the identified spruce trees. Light is often the limiting factor for tree growth in spruce-northern hardwood forests. As the term implies, non–commercial release does not result in a timber harvest. All culled trees remain on site, becoming snags and eventually coarse woody debris, increasing the structural complexity of the stand and mimicking late successional forest structure. Because non-commercial release does not require heavy machinery and the resulting ground disturbance, it can be implemented in difficult-to-access areas and sensitive ecosystems, like riparian areas, steep slopes, or sites with fragile soils.

Example of spruce suppressed by a hardwood midstory © Jordan Luff/TNC

Steps of release

The process of spruce release starts well before release practitioners put their boots on the ground. This guide moves step by step through the release process, briefly outlined below.

1. **Create Goals and Strategies:** Define the goals of restoration and develop a plan to reach the goals.

2. **Select Restoration Units:** Choose units that align with restoration goals and can realistically be treated.

3. **Scout Sites**

    a. Desktop Scouting: Use satellite imagery and other datasets to assess restoration units for release potential and identify potential target areas.

    b. Field Scouting: Visit units prior to implementation to confirm accuracy of desktop scouting, identify target areas, and strategize the approach to treatment.

4. **Delineate Gaps:** Identify which hardwoods will need to be culled to effectively release the target spruce, and designate hardwoods that will not receive treatment.

5. **Create Gaps:** Craft appropriately sized and spaced gaps safely, effectively, and efficiently.

    a. Mechanical Gap Creation

    b. Chemical Gap Creation

6. **Map and Report Progress:** Document activities on a digital map and create reports that provide clear communication with landowners, partners, and the restoration community of practice.

Create Goals and Strategies

Spruce release projects serve restoration goals using pre-determined strategies. Goals and strategies may change from site to site. Scouting, described later, will inform what goals and strategies may be feasible on a given site. The most successful projects are built on a shared understanding and agreement on site goals between the landowner, resource specialists, and on-the-ground practitioners. Landowners set high-level release goals and ensure that goals adhere to relevant regulations and forest management plans. Resource specialists provide clarity and definition to those goals through the lens of their respective expertise. On-the-ground practitioners use site goals and resource considerations to craft site strategies. Practitioners should employ their understanding of spruce ecology and stand dynamics to craft a strategy that best achieves site goals, given on-the-ground limitations like difficulty of access, stand density, and terrain. In summary, goals determine strategy; strategy determines on-the-ground tactics.

Goals

Site goals depend on landowner priorities, restoration objectives, landscape context, and existing forest condition. The following are common site goals:

- **Enhancing spruce connectivity:** Improving connectivity between disparate spruce-dominant forests via release. Release units may be positioned between well-established, functional, spruce–hardwood systems.
- **Restoring red spruce community composition:** Many red spruce–northern hardwood systems are compositionally departed from reference. Resources like Byers et al. (2010) and Brown et al. (2026) describe reference species composition in a variety of red spruce community types. Practitioners should consult local or regional science when determining appropriate community species composition.
- **Improving terrestrial wildlife habitat:** Threatened and endangered wildlife that depend on spruce systems have driven many restoration projects. For example, research shows that northern flying squirrel populations begin to dramatically increase when the forest canopy consists of at least 30% spruce, before plateauing when spruce canopy coverage exceeds 50% (Ford et al., 2004). Therefore, restoration goals centered on improving northern flying squirrel habitat have aimed to put spruce–hardwood stands on a trajectory of achieving between 30% and 50% spruce canopy coverage.
- **Improving aquatic wildlife habitat:** Spruce cover provides perennial shade atop cold-water streams. Culling hardwoods to release spruce can increase levels of large woody debris in streams and drainages, increasing aquatic habitat complexity and improving stream access to the floodplain. Spruce forests also create thick organic soils. These soils function as a sponge during precipitation events, absorbing water and slowly releasing that water to streams. This absorption and slow release helps hold cold water high in headwaters, keeping streams cooler. If managers are focused on improving cold-water stream habitat, project goals could include increasing spruce canopy cover within high-priority headwater catchments.
- **Enhancing late successional forest conditions:** Many of today's spruce–hardwood forests in the central Appalachians are even-aged, mid-successional forests that have not yet developed functional late successional traits. Managing forests for a variety of successional classes, including late succession and old growth, can enhance forest resilience and improve habitat at a landscape scale.

This list of goals is not exhaustive. Managers should tailor site goals to address local ecosystem threats and management concerns. Sites can have multiple goals; however, it is useful to designate a primary goal, followed by secondary goals. Creating a hierarchy of goals will help on-the-ground practitioners prioritize areas to treat and choose appropriate treatment strategies if goals conflict.

Strategies and tactics

Site goals determine the strategies employed by on-the-ground practitioners. Strategies should be selected in the service of achieving the site goal. Site strategies can include:

- Connecting disjunct patches of red spruce in the canopy by establishing a corridor of released spruce in canopy gaps that connect patches of well-established canopy spruce
- Concentrating release efforts in areas of high ecological importance, like riparian corridors
- Enhancing stand heterogeneity by scattering gaps throughout a unit
- Maintaining late successional forest characteristics by only releasing red spruce suppressed by small hardwood stems, leaving the largest and oldest hardwoods intact

Strategies are translated to tactics. Tactics are the on-the-ground actions that implement site strategy. Multiple tactics and strategies can be employed to achieve a desired site goal. Tactics may include:

- Altering gap size and location
- Adjusting tree species and size classes to keep or cull
- Delineating areas of a treatment unit to avoid or prioritize
- Choosing mechanical or chemical release methods
- Choosing crew size and management approach

The following examples demonstrate how to set site goals based on landscape characteristics and how those goals inform site strategy.

Example 1

Example 1 shows a 228-acre non-commercial spruce release unit bounded to the west by a ridgeline and the east by a river. Note the large green coniferous patches to the west and east of the unit. The restoration goal for this unit was to improve spruce connectivity, enhancing spruce cover from one patch of conifer cover to another across the unit. To achieve this goal, we used a connect-the-dots strategy, placing gaps in rough lines to connect the disparate patches of dense spruce cover to the east and west of the unit. To efficiently and effectively implement this strategy, we prioritized creating gaps on north-facing slopes, which generally have less hardwood competition and more spruce coverage. We avoided working in areas of dense beech brush, which are common on south-facing slopes, and on extremely steep slopes for crew safety. This strategy and associated tactics resulted in pockets of released red spruce forming corridors of connection across the elevation gradient.

The light blue polygons show created canopy gaps. In total, there are 92 gaps within the unit, with an average size of .06 acres. The largest gap is 0.37 acres and the smallest gap is 0.03 acres. Gap number, size, and placement will be variable from unit to unit depending on site goals, strategies, tactics, and pre-existing stand conditions.

Example 2

Crews observed numerous late successional forest characteristics in the western part of this 27-acre unit, including large blowdowns, evidence of trees having germinated on nurse logs, and scattered large-diameter trees. Conditions observed in these western reaches reflect the desired future condition for the entire unit. As such, crews left the western portions of the unit untreated, focusing treatment eastward. Given the high density of spruce in and around this unit, restoration only required a light management touch. Therefore, gaps were kept smaller than normal and dispersed relatively evenly, recognizing that the unit was already nearing an appropriate restoration trajectory. This lighter touch approach allowed crews to focus on improving late successional forest characteristics, making smaller gaps more in line with annual canopy turnover rates in older forests. In total, only 15 gaps were created, averaging 0.13 acres, with the largest gap at 0.29 acres and smallest gap at 0.06 acres.

Desired forest conditions were observed in the western reaches of this unit. Crews opted to leave this area untreated, instead focusing on creating small canopy gaps to improve late successional forest structure while opportunistically releasing spruce. © Will Evans/TNC

(continued)

Example 2
(continued from previous)

Evidence of late successional forest characteristics in the western portions of example 2 include instances of trees having germinated on long-decayed nurse logs and multiple cohorts of spruce, including snags, coarse woody debris, canopy trees, and midstory trees. This section of the unit was left untreated, as it already resembled the desired future condition. © Will Evans/TNC

Forest Stewardship Council (FSC) considerations

by Tal Jacobs

In the eastern United States, active management frequently occurs in the context of a third-party certification standard. Such standards aim to build stakeholder and consumer confidence that a forest's management meets defined and verifiable criteria. While certification standards differ, they typically address themes of harvest sustainability, conservation of ecological and cultural resources, and responsible consideration of social and economic impacts from management activities. In the eastern United States, and within the red spruce range, certification most commonly occurs on private and state lands.

Before a manager engages in red spruce restoration on certified forestland, they should evaluate and adapt their prospective treatment to align with any relevant certification standard. This alignment is feasible, managers have successfully deployed this manual's goals, strategies, and tactics on certified forest. This section will describe that experience and highlight considerations that practitioners will likely face in the context of certification. We explore these considerations primarily from our experience in Forest Stewardship Council® (FSC®) certification. However, these learnings should not be considered prescriptive for FSC® or any other compliance, but rather an illustrative lens for topics emphasized across multiple standards.

Particularly in the southern and central Appalachians, the presence (including future potential) of a red spruce component will likely merit special designation to a forest stand under certification. Such attribution occurs for many of the same reasons that red spruce forests are critical restoration targets: rarity, underrepresentation, their special complements of biodiversity, and their unique dynamics which can result in especially high delivery of certain ecosystem services. In our experience with FSC®, red spruce systems (along with their matrixed northern hardwood counterparts) called for explicit designation as High Conservation Value Areas (HCVAs) and Representative Sample Areas (RSAs). Both designations demand clear rationales and appropriate precautions for active management within such defined areas.

In a red spruce–northern hardwood HCVA, we initiated active management specifically to protect and advance the special attributes of the area's designation—namely a functional red spruce system and its species/system associates. Treatment design relied on a review of forest and biological inventory (including natural heritage databases), a thorough site assessment for current conditions and restoration potential, a literature review of species/system traits and vulnerabilities, and expert consultation. Biologist consultation revealed that the adjacent mature spruce stand, although it had not been surveyed, had a reasonable likelihood of hosting the recently delisted northern flying squirrel (*Glaucomys sabrinus*). This resulted in various treatment modifications, including biologist recommendation to maintain untreated hardwood corridors through the treatment area. These aimed to maintain squirrel habitat connectivity as release treatment areas matured into preferred habitat. The HCVA also received its designation for hosting rare flora and fauna not directly tied to the presence of a spruce system. Treatment design mitigated adverse impacts to these species by avoiding known areas of occurrence, modifying treatment tactics, and providing the crew with a species identification guide to locate and adapt treatment around new occurrences.

As with the HCVA treatment site, the ecological footprint of specially designated systems may span ownership and management boundaries. Collaborative, cross-boundary treatment can allow more efficient and impactful entries to support the special ecosystem attributes of such areas. At our HCVA treatment site, managers worked across two certification standards for a single entry, combining considerations and goals for mutual support of the site's desired conditions.

Most treatment modifications hinged on site-specific considerations for ecologically and socially responsible chemical use. Like FSC®, certifications emphasize some form of risk assessment for chemical treatments. Our treatment design process considered broader themes, including:

- Viability of alternatives to chemical treatments (e.g., mechanical)
- Evaluation of relative risk for multiple chemical options
- Strategies to reduce overall chemical volume
- Timing and notification to avoid potential stakeholder conflict

Our evaluation of species and system risks led to modifications, including:

- For a rare salamander species known to exist in the vicinity:
  - No basal spray to stems growing from potential habitat (i.e., rocky crevices, boulder fields)
  - No chemical application onto loose/fissured bark, which provides potential habitat
- Withholding chemical application for aquatic and riparian buffer areas

Importantly, treatment modifications for species of concern should serve not only to avoid immediate adverse chemical effects, but appropriately mitigate habitat impacts from treatment (e.g., changed moisture/temperature regimes, forest structure, species composition). While practitioners can control the scale and intensity of spruce release treatments for compatibility with additional species/systems of concern, there may be instances in which desired future conditions and near-term impacts conflict with the needs of current species of concern on a site. These cases require careful deliberation on the impacts of treatment versus no treatment. For competing species/systems, decisions should consider their relative projected future threats, their adaptive or restoration potential, and their associated ecological and social values.

The dramatic underrepresentation of red spruce–northern hardwood matrix in the central and southern Appalachians made our area's RSA designation a driving determinant for treatment design. Desired future conditions hinged on species and structural composition representative of a literature-informed reference state, including metrics supportive of current species of concern and their associations. Local or regional system sub-types should also receive attention during management planning. For instance, the reference southern Appalachian spruce forest for our FSC® treatment area contained unique subvariant characteristics of rhododendron understory and presence of eastern hemlock. Thus, our treatment aimed to preserve and promote these components, including targeted release of vigorous midstory hemlock.

Managers should not view forest certification as a barrier for practicing red spruce restoration with release treatments. However, certification can create additional considerations for practitioners, particularly regarding chemical use and specially designated areas. With this awareness, we've found that the heightened attention of certification can improve the procedures of adaptive management and the likelihood of good management outcomes.

Select Restoration Units

Historic range considerations

Spruce restoration should focus on areas within the former historic range of spruce predicted to remain climatologically suitable for spruce into the future. In West Virginia, practitioners have utilized the Byers et al. (2010) red spruce cover map to determine areas that previously supported spruce forests prior to large-scale deforestation. Mapping of spodic soils, a soil characteristic driven by an historic abundance of spruce and other conifers, has proved to be a reliable tool for determining restoration sites on the Monongahela National Forest. Practitioners should consult available resources for their region to locate suitable areas for spruce restoration.

Landscape-scale considerations

When identifying release units, assess opportunities to expand current extent and habitat connectivity at the landscape scale. Landscape-scale considerations should not be bound by property lines or state borders. Instead, they can be delineated by a variety of natural features, including watersheds, migratory pathways, mountain chains, and ecosystem types. The goal of restoration is not only to increase canopy coverage of spruce, but to connect disjunct stands, creating self-sustaining healthy red spruce influenced–forests that restore red spruce ecosystem functionality at a landscape level. The number of stands to restore and the percentage spruce canopy cover to achieve desired ecosystem functions will vary across landscapes.

For example, in the Monongahela National Forest, we begin at the watershed scale and zoom into areas approximately 1,000–5,000 acres to identify new units for release. Within the 1,000–5,000 acre area, we may look for slopes with a robust spruce canopy at the top that can be connected with another spruce stand along a stream at the bottom. The release units would be drawn to connect these two stands.

Stand-level considerations

Suitable release units should have abundant understory spruce suppressed by canopy hardwoods. Spruce seedlings and saplings do not have to cover the entire release unit but should be extensive enough that their release will put the unit on a path toward reaching the target spruce canopy coverage.

When spruce are already present in the canopy, the need for treatment decreases as the percentage of spruce in the canopy increases. For example, release treatment in a unit with 20% spruce canopy coverage can be less aggressive than release treatment in a unit with 5% canopy coverage. Large units (i.e., >50 acres) are preferable to small ones (i.e., <50 acres), as they allow a greater degree of flexibility to release the highest quality spruce and leave less vigorous spruce suppressed while still meeting treatment goals.

Scout sites

Desktop scouting

Utilize desktop scouting to identify areas that are suitable for achieving landscape-scale restoration goals (see Create Goals and Strategies), potential release units, and conifer stands within release units. Satellite imaging is an effective way to locate spruce within a unit. Use the most up-to-date leaf-off imaging to identify potential conifer populations by looking for evergreens amidst deciduous trees. Relief or topographic maps can be utilized along with road maps to assess the best access points to the unit and determine travel times. Some areas may have additional data, such as spodosol maps, historic spruce coverage maps, or forest-type modeling that could help identify areas with restoration potential. Desktop scouting before fieldwork can save time and improve efficiency once field scouting and treatment begins.

Field scouting

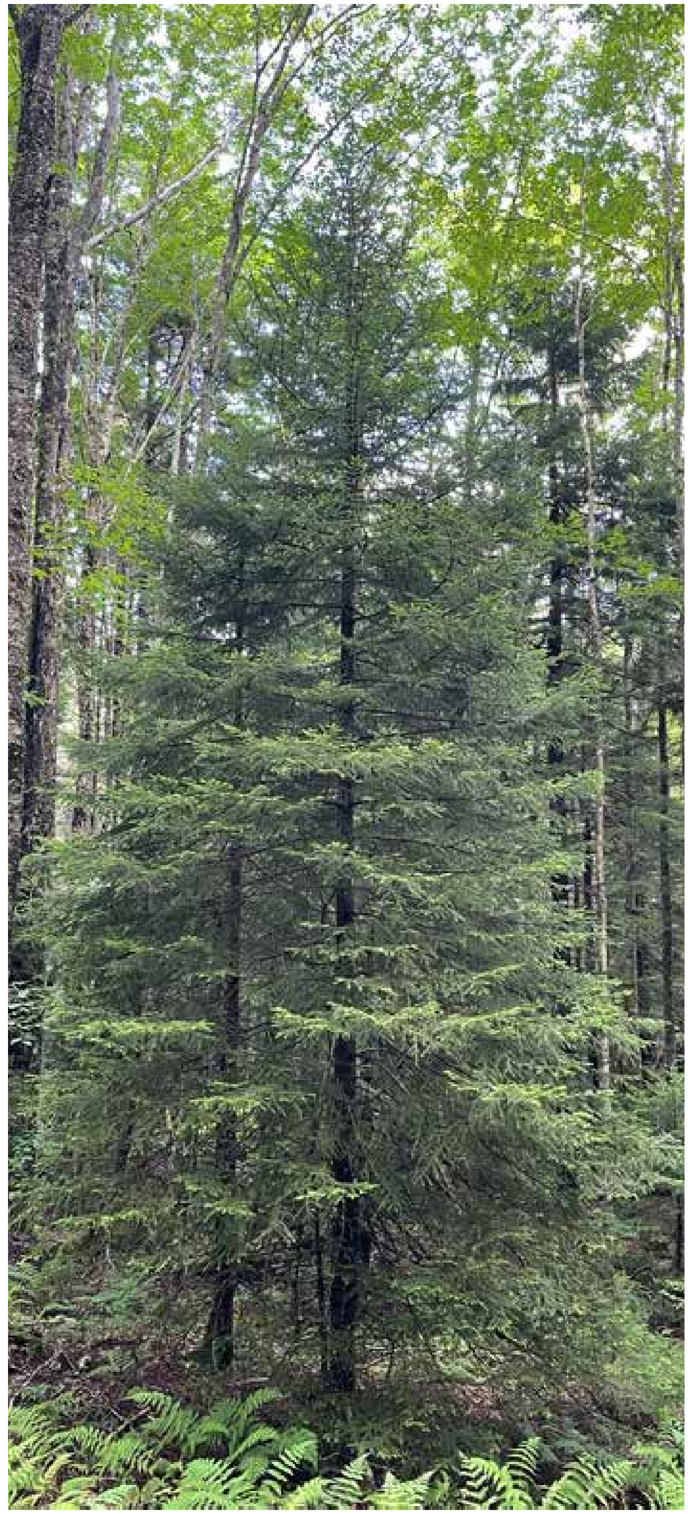
Field scouting is critical to understanding on-the-ground conditions in a unit, and thus essential to adequately formulate a treatment strategy. Utilize a mobile mapping app to record what portions of the unit have been scouted, and to make location-specific notes that can be referenced later by crews. FieldMaps and Avenza are two commonly used, reliable, and versatile mobile mapping applications. When scouting, crew members should take notes on spruce locations, hardwood tree species, changes in forest type, percent spruce canopy coverage, unit boundaries, access points, hiking time, and other factors that inform treatment plans. Every acre of a unit should be scouted in the field, even if aerial imagery shows no spruce presence. Oftentimes, even high-resolution leaf-off aerial imagery fails to adequately show conifers in the mid- and understories of stands. Stand characteristics like beech brush density, species diversity, and hydrologic features are only visible on the ground and need to be incorporated into decision making. Notes taken during scouting are invaluable when returning to a unit treatment so that crews are prepared and can strategize a plan of action before arriving on site. Field scouting is a stand-alone exercise. Crews should not scout and begin treatment simultaneously. Scouting ahead of time will allow crews to quickly assess the unit without wasting time and energy hauling equipment to areas that may not require treatment.

Delineate Gaps

Delineating an appropriately sized gap is the most difficult part of non-commercial spruce release. Thorough scouting, as previously described, is the foundation of proper gap size and placement. Using observations from desktop and field scouting, combined with site goals, strategies, and tactics, practitioners can begin the process of gap delineation and hardwood culling. Using the principles described below, crews can either delineate all gaps within a unit prior to release treatment, or for added efficiency, delineate gaps and implement treatment simultaneously.

Identifying releasable spruce

Generally, practitioners should target the tallest, most vigorous spruce for release. However, the definition of a releasable spruce will vary from unit to unit as tree vigor, size, and density are highly variable across the landscape. Spruce tree vigor can be quickly assessed visually. Spruce self-prune when suppressed for extended periods of time. Spindly, lollipop-shaped trees are poor targets for release. While they may respond to increased sunlight, their longevity is questionable. Instead, target healthy trees that still have living lower branches. Spruce that look like a suitable Christmas tree are highly vigorous, albeit rare. Look for spruce near the canopy. The taller the tree, the quicker it will occupy the canopy and begin casting shade. In the Monongahela National Forest, spruce 10 feet or taller are generally good candidates for release given average suppressed spruce height and average canopy height. Restoration practitioners in the southern Appalachians have reported a lack of suppressed spruce trees in or above this size class. Therefore, practitioners in this geography may need to release smaller trees. Gaps created above seedlings or small saplings will likely close before the released tree has an opportunity to reach the canopy. To mitigate this, gaps will either need to be made larger to ensure that released tree has adequate time to reach the canopy, or the unit will have to be revisited and released again in the future.



This spruce, while suppressed, still retains its lower branches. All branches are full of needles, and the tree has a Christmas tree-like form. This tree is highly vigorous and would be an excellent candidate for release. © Will Evans/TNC

This thin spruce in the foreground has lost most of its lower branches and now resembles a lollipop. Trees like this are generally low vigor and poor candidates for release.
© Will Evans/TNC

Effectiveness of Release

Gaps that are too small, too large, too clustered, or too scattered may fail to achieve restoration goals or result in negative impacts to stand structure and composition. Gaps should be large enough that the spruce targeted for release will be able to reach the canopy before the gap closes, but small enough to fall within an appropriate range of variability for natural disturbance regimes in a spruce–northern hardwood system, and at a high enough density to reach restoration goals, all while retaining or improving localized biodiversity and appropriate forest structure. We walk through how to balance each of these factors below.

Releasing clusters, not trees

One spruce standing amongst a sea of hardwoods is not going to influence ecosystem function. As previously stated in the spruce ecology section, two of the pillars of spruce ecology and ecosystem engineering are shade and soils. Clusters of canopy spruce create more shade and build up organic matter in soils faster than lone trees.

With these ecological functions in mind, prioritize releasing clusters of spruce, not individual trees. Search for clusters of suppressed, yet vigorous, midstory spruce to release in one gap. Reasonably sized clusters could be as small as three to four trees or could be as numerous as >50 trees. Trees can be considered clustered if they are reasonably close to one another. Generally speaking, trees more than 60 to 90 feet apart are too spread out to be considered a cluster. As a rule of thumb, consider the ratio of spruce released to canopy hardwoods culled. One spruce released for every canopy hardwood culled, a 1:1 ratio, is ideal. Ratios of 1:2 and 1:3 are also good candidates for release. Conversely, ratios of 1:10+ are less desirable, resulting in inefficient use of crew time compared with the benefit of spruce released. Of course, these ratios will vary with stem density, site index, and canopy height within any given unit. The goal should be to maximize the ratio of spruce released to canopy hardwoods culled.

However, there are caveats. "Dog-haired" stands with high stem density, high competition, and low vigor should be left unreleased. These stands can look like a wall of lollipop spruce. Releasing dog-haired stands of spruce will result in growth of these trees, but without thinning the spruce, they will compete with one another and may fail to ascend to the canopy. If spruce in this condition are the only option for release, it may be beneficial to explore additional treatment options, such as thinning, to reduce competition and increase the likelihood that they will reach the canopy once released.

Maximizing the ratio of hardwoods culled to spruce released translates to releasing clumps of spruce. The picture above represents a roughly 1:2 ratio with four to five tall, vigorous, spruce released and eight to nine hardwoods culled. © Will Evans/TNC

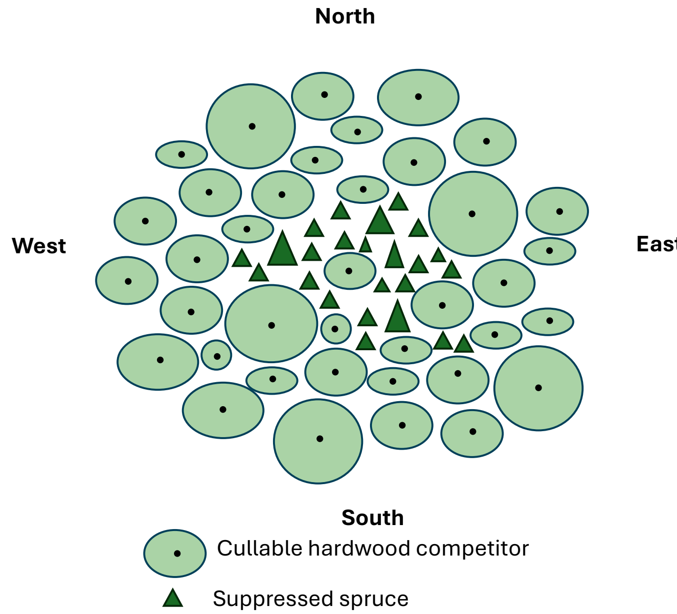
Dog-haired stands of spruce are nearly impenetrable, with high stem density and resulting high competition amongst trees. These are poor candidates for release without thinning. © Noah Reed/TNC

Appropriate gap size

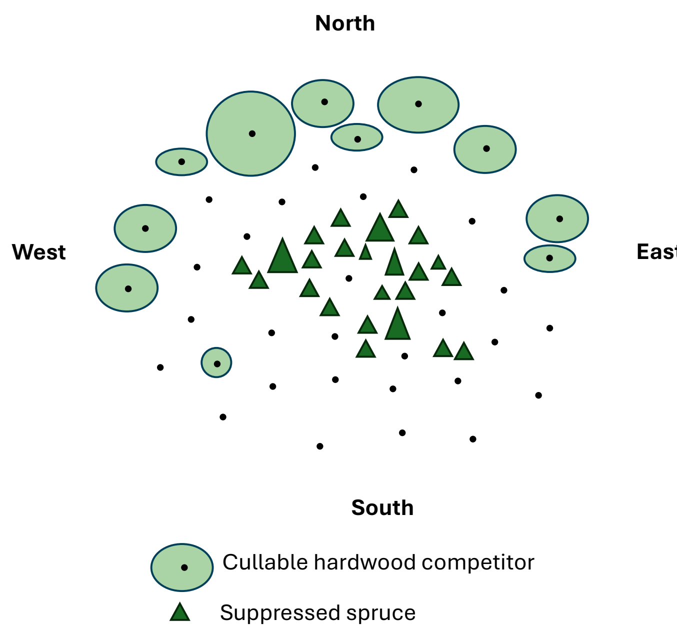
Gaps should be large enough to provide adequate light and space for target spruce to ascend to the canopy. The historic range of variability for canopy disturbance in spruce-influenced systems can serve as a guide for making appropriately sized gaps. For example, every hardwood tree in a 40-acre unit could be culled, leaving only spruce standing. This would release the spruce and the spruce would ascend to the canopy, but forest succession would be reset, key components of wildlife habitat lost, and forest structure homogenized.

In practice, gap size is related to the size of the target spruce. As a rule of thumb, for spruce 10–30 feet tall, snag all overstory and midstory stems directly atop and up to 50 feet away from any spruce targeted for release. For spruce greater than 30 feet tall, snag all overstory and midstory stems overtopping or competing with the target spruce and stems up to 25 feet from the targeted spruce. Prioritize culling hardwood trees to the south, east, west, and uphill of the gap to increase the amount of light reaching the target spruce.

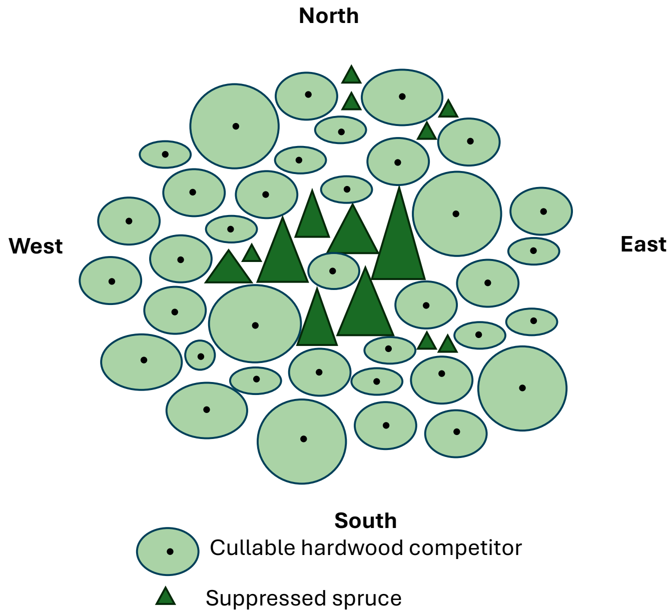
As noted previously, there may be instances when suppressed spruce in a restoration area are universally smaller than 10 feet. In these situations, land managers will need to determine whether it is ecologically appropriate to create larger gaps to release small spruce in one event, or whether multiple release treatments are more appropriate. The following diagrams provide an example of right-sizing gaps to the size of spruce targeted for release.



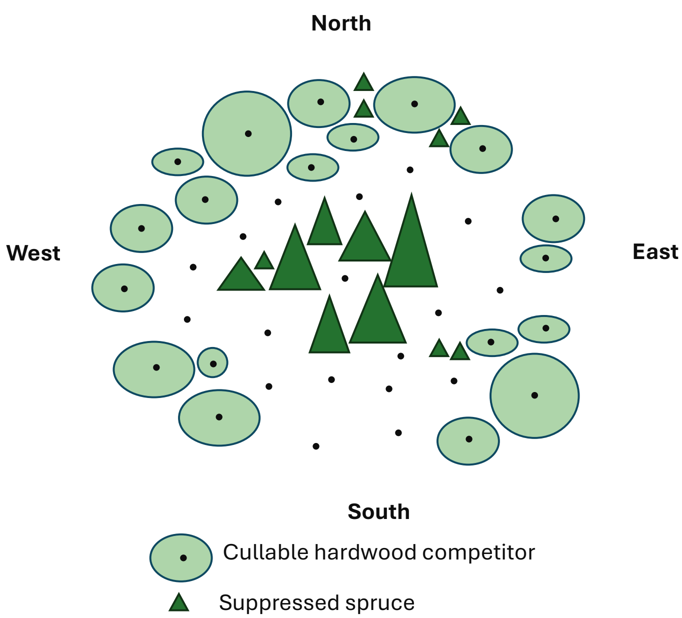
Hardwood trees that are options for culling to release a stand of suppressed spruce.



Culled hardwoods to release these smaller sapling spruce. The release aggressively opens the canopy to the south, ensuring that the gap will stay open and receive adequate sunlight for as long as possible.



Hardwood trees that are options for culling to release a stand of suppressed spruce.



Note that fewer hardwoods are culled to release these larger midstory spruce. The release still prioritizes opening the southern exposure but does not have to be as aggressive to ensure that gap stays open long enough for these trees to reach the canopy. The large spruce trees in the center are the release targets. The small spruce on the periphery of the gap are not targeted for release. These small trees will receive some additional light, but because of their small size relative to the stand average, they are not intentionally targeted for release.

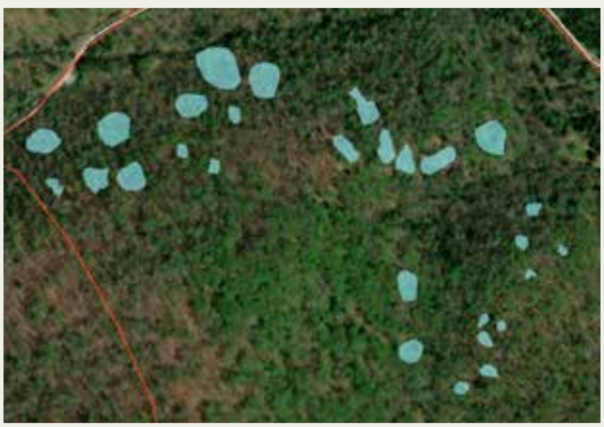
Forested conditions where it makes ecological sense to make a gap larger than one acre are likely exceedingly rare. Canopy gaps that would occur naturally in a late successional spruce–northern hardwood forest due to windthrow, insects, disease, or natural canopy mortality are small. Research in eastern late successional forests shows that red spruce need, at minimum, canopy gaps of 0.1 acres to ascend to the canopy (Barton et al., 2018). The authors have created hundreds of gaps that average 0.27 acres. Late successional northern hardwood forests have average natural gap sizes ranging from .005 to .03 acres (or 215 to 1,300 square feet), meaning that understory spruce typically experience multiple release events before ascending to the canopy (Barton et al., 2018; Oswald et al., 2024). For the authors, our objectives are to make gaps large enough to release spruce in one release event to increase our efficiency across space and time. Practitioners can be adaptive in gap size given the targeted nature of this work. However, practitioners should be mindful that exceedingly large gaps may result in unintended ecological consequences, like reduction in soil moisture or breaks in forest connectivity.

Gap buffers

When creating gaps throughout a unit, it is critically important to leave buffers of living hardwoods between clumps of released spruce. Retaining hardwood buffers helps ensure maintenance of mast sources for wildlife forage, reduces canopy spruce exposure to windthrow, and helps crews understand gap boundaries. Ensuring hardwood buffers around gaps is especially important in areas being treated with a high density of gaps. See Example 3 on the next page.

Example 3

Gaps are shown in light blue. This area had many releasable spruce trees. We could have easily allowed our canopy gaps to bleed into one another. Instead, we ensured that gaps were buffered by a thin band of living hardwoods. By breaking up these larger tracts of releasable spruce into distinct gaps, we are more closely emulating natural disturbance in spruce–northern hardwood systems and preventing the creation of monocultures in these stands. At minimum, a row of living hardwoods should be left as a gap buffer (roughly 20 yards); ideally several rows of hardwoods are left untreated to more clearly delineate gap boundaries. There is no upper limit to gap buffer size. When making larger gaps, consider expanding gap buffers to maintain appropriate hardwood diversity and create adequate windbreaks. Our goal is not to create a spruce monoculture. Instead, we want to elevate spruce as a dominant or codominant canopy tree within a red spruce–northern hardwood matrix.



Although there is a high density of canopy gaps mapped in this area, a sufficient component of hardwoods were retained around each gap to reduce windthrow potential and maintain localized biodiversity.

Monoculture stands of red spruce, like those pictured above, are not the restoration goal. Retaining select hardwoods during spruce release can help ensure that localized biodiversity is maintained and forest structure remains complex. © Will Evans/TNC

Retaining and/or improving biodiversity and forest structure

Spruce–northern hardwood forests have a high diversity of tree species, including several mast-producing species critical for wildlife. Therefore, many hardwood species should be retained during spruce release. These species are variable across geographies. Generally, species to retain are locally rare species, mast-producing species, and species that are under stress from pests and pathogens. In West Virginia, these principles translate to retaining the following species:

- Red spruce (*Picea rubens*)
- Balsam fir (*Abies balsamea*)
- Hemlock (*Tsuga canadensis*)
- Butternut (*Juglans cinerea*)
- Chestnut (*Castanea dentata*)
- Disease-resistant beech* (*Fagus grandifolia*)
- Hickory (*Carya* spp.)
- Oak (*Quercus* spp.)
- Ash (*Fraxinus* spp.)
- Mountain ash (*Sorbus americana*)
- Apple (*Malus domestica*)
- Yellow poplar (*Liriodendron tulipifera*)
- Aspen (*Populus* spp.)
- Hawthorn (*Crataegus* spp.)
- Black cherry** (*Prunus serotina*)
- Basswood (*Tilia americana*)
- Serviceberry (*Amelanchier arborea*)
- Witch hazel (*Hamamelis virginiana*)
- Mountain holly (*Ilex mucronata*)
- Hop hornbeam (*Ostrya virginiana*)
- Fraser magnolia (*Magnolia fraseri*)
- Cucumber magnolia (*Magnolia acuminata*)
- Yellow birch** (*Betula alleghaniensis*)

The following have been deemed appropriate species to cull throughout the Monongahela National Forest:

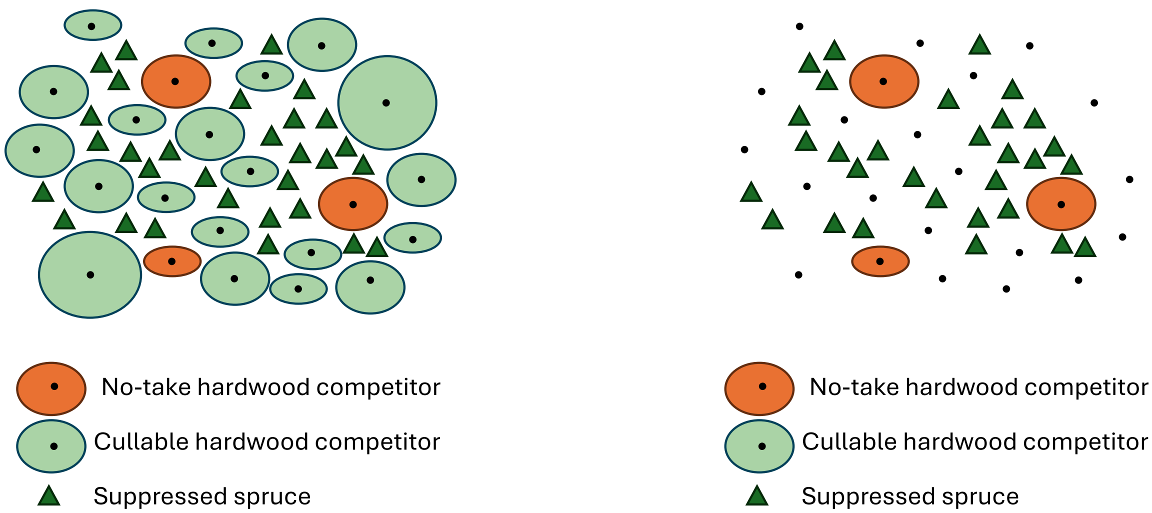
- Red maple (*Acer rubrum*)
- Sugar maple (*Acer saccharum*)
- Striped maple (*Acer pensylvanicum*)
- Black birch (*Betula lenta*)
- Diseased beech* (*Fagus grandifolia*)
- Sometimes black cherry** (*Prunus serotina*) and yellow birch** (*Betula alleghaniensis*) depending on the site

* American beech in the central Appalachians is often afflicted with beech bark disease. This fungal disease creates blistered bark and results in heavy suckering from infected trees, creating beech brush. Trees under 9" DBH, regardless of condition, can be culled. Trees above 9" DBH that appear healthy or moderately resistant to beech bark disease should be retained. An estimated 1% of beech are resistant to the disease. If large smooth-barked beech are found, consider them resistant, and thus a "no-take" tree. Some herbicides, such as triclopyr, do not translocate into root systems of interconnected beech stems. If treating beech brush near resistant beech trees, consider using a triclopyr-based product to prevent unintended impacts to potentially resistant beech. However, glyphosate and imazapyr are known to translocate through interconnected root systems. Avoid using glyphosate, imazapyr, and other herbicides with high translocation potential near resistant beech.

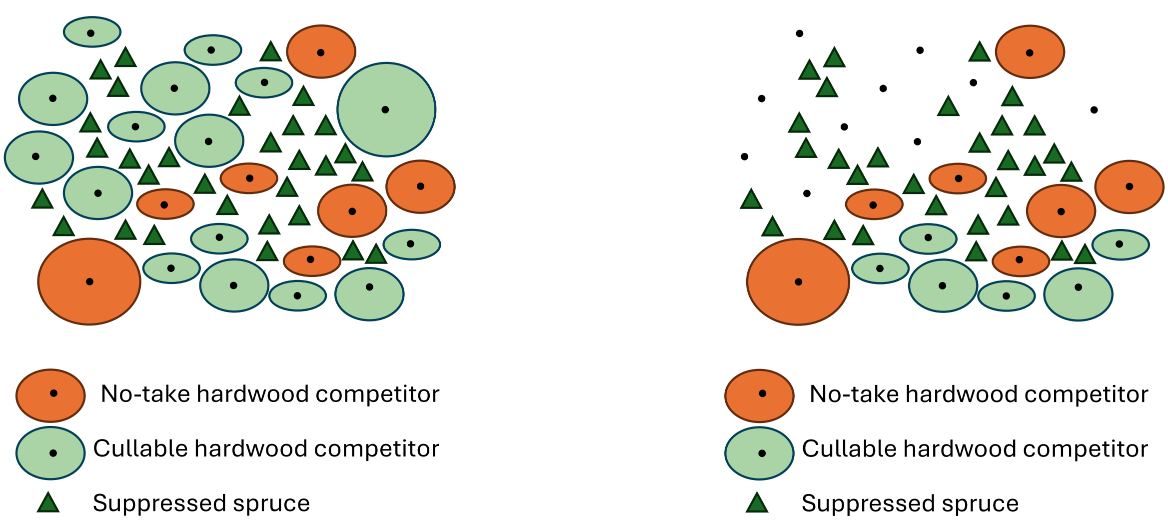
** Black cherry and yellow birch retention needs are highly variable across sites. Black cherry produces soft mast valuable to wildlife and has a narrow crown and sparse leaf coverage that generates little shade. However, there are instances where stands may be dominated by large cherry. In these circumstances, black cherry can be selectively and infrequently culled during release. Yellow birch, like black cherry, has important wildlife value for species like flying squirrels that rely upon the flaky birch bark for nesting material. However, some stands may be dominated by yellow birch. In instances where yellow birch is the dominant or co-dominant species in a stand, it may be selectively and infrequently culled to release spruce. Yellow birch with bright, pale-yellow bark that sheds in strips or that have cavities in the main stem should be retained as valuable wildlife habitat, particularly for flying squirrels.

Depending on gap size, some retained hardwood trees can sit within gap boundaries without compromising the effectiveness of release. For example, a 0.25 acre composed of maple and black birch with several retained basswood and serviceberry can still be a functional gap if the retained trees don't completely shade the gap. However, releasing only a handful of spruce in a 0.05-acre gap with overtopping retention trees may fail to open the canopy enough to dramatically improve light availability. In other words, not all trees have to be culled within a gap to create an effective release. The larger the gap, the more opportunity to retain hardwoods and still effectively release spruce. The diagram below is an example of retaining ecologically important tree species and leaving spruce suppressed.

Retaining No-Take Trees While Ensuring Effective Gap Creation



In this instance, the retention trees are small enough and sparse enough to enable an adequate gap to be created.



Removing the cullable hardwoods along the bottom edge of this stand will not adequately release the spruce below, given the density and size of no-take trees. In this situation, it is best to leave the bottom right portion of the stand untreated.

Similar considerations apply to forest structure. The largest trees within a restoration unit should be retained as legacy trees. These legacy trees are left untreated so that they may grow older and bigger. When legacy trees eventually die, they will make large canopy gaps, create a significant pulse of coarse woody debris, and potentially become nurse logs for the next cohort of spruce. Gap creation is just the first step in a process we hope will become self-sustaining as today's legacy trees will become the next iteration of canopy gaps in the intermediate future.

Spruce restoration is just as much about promoting a self-sustaining late successional forest structure as it is about increasing spruce canopy coverage.

When to leave spruce suppressed

Not all vigorous midstory spruce need to be released. Leaving spruce suppressed for an ecological goal may be a component of your restoration plan. "No management" is the first option for most forest management plans. Crews should be empowered to make "no management" decisions in the field. To summarize the previously outlined gap delineation guidelines, spruce should be left unreleased if they meet any of the following criteria:

- Spruce are overtopped by no-take tree species or no-take size classes. No-take size classes are variable based on unit conditions but generally include trees with four or more stems originating from the same place and trees larger than 30 inches DBH.
- Spruce trees are alone as individuals rather than in clumps.
- Spruce fall within a hardwood buffer.
- Spruce are in dog-haired stands.
- Spruce are too small to reach the canopy in one release event.
- The ratio of hardwoods culled to spruce released is exceedingly high based on typical ratios within the unit.
- There are non-native invasive species (NNIS) within proposed gaps. Increasing sunlight reaching NNIS will encourage their proliferation.

**Treatments should retain components of a stand with late successional characteristics. In this instance, a maple tree significantly larger than the stand average, with spreading branches, was retained as a legacy tree. Retention of this tree maintains or enhances structural complexity that is common in healthy red spruce–northern hardwood systems.
© Will Evans/TNC**

Avoiding common pitfalls

The most common pitfall in non-commercial spruce release is "gap creep." Gap creep happens when crews find a cluster of releasable spruce and start culling hardwoods without first clearly delineating the gap boundaries. When gap creep happens, gaps often become excessively large, distinct gaps bleed into one another, hardwood buffers are lost, and more hardwoods are culled than intended. To get a proper sense for gap boundaries, crews should walk through the stand of spruce to be released, look for no-take tree species and size classes, determine a rough ratio of spruce released to canopy hardwoods culled, and outline the boundaries of the gap before culling any trees. Avoiding this pitfall becomes particularly important when crews are tired. When fatigue sets in, crews are less likely to adequately scout gaps and walk gap perimeters. Crew leaders should remain mindful of this situation, especially toward the end of the day, the end of the work week, and the end of the field season.

The second major pitfall is attempting to release spruce in thick stands of beech brush. In stands previously dominated by beech that now contain trees succumbing to beech bark disease, beech brush can be prevalent. Beech brush can form thickets of <1" DBH stems, capable of easily outcompeting sapling spruce. Beech brush thickets can include hundreds of individual beech stems. Treating such high stem densities is generally an inefficient use of time. Any beech stems inadvertently missed during treatment will be released and soon outcompete the released spruce. Spruce release in dense stands of beech brush is a poor use of time and resources.

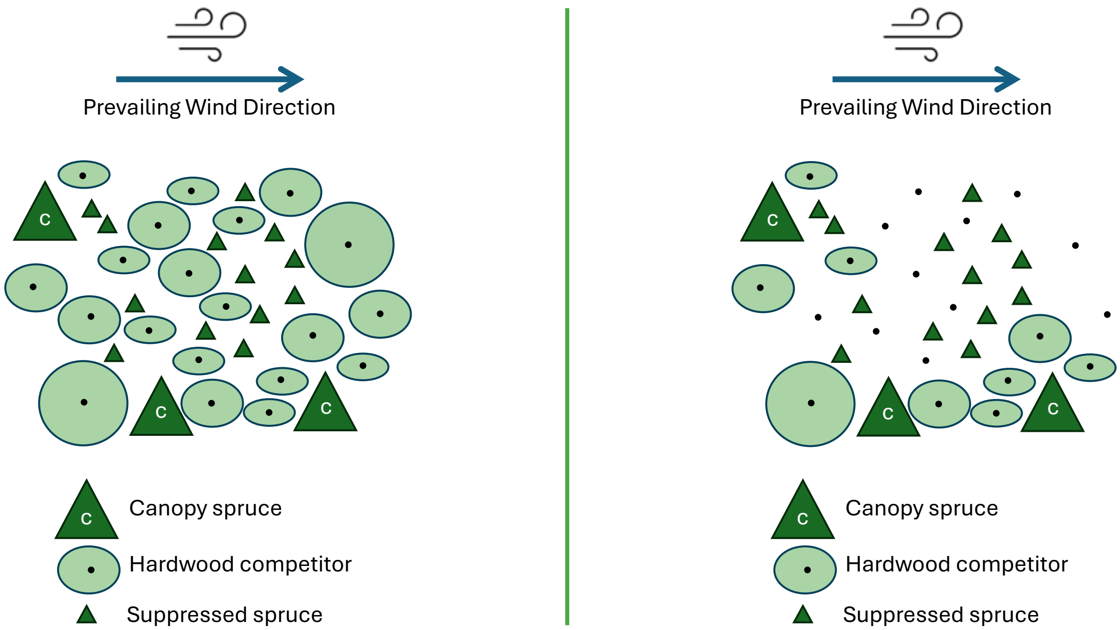
The third and final common pitfall to avoid is exposing canopy spruce to windthrow. In acidic soils common within its range, spruce are shallow rooted, making them highly susceptible to windthrow. Creating canopy gaps near or around canopy spruce

Diseased parent beech (left) and accompanying beech brush are shown here. Spruce suppressed by dozens of beech stems are best left unreleased given low efficiency and the high quantity of herbicide needed for a successful release. © Will Evans/TNC

Retain canopy hardwood trees touching at least two sides, preferably three sides, of the canopy spruce to serve as a windbreak and reduce windthrow potential. © Will Evans/TNC

can expose them to higher winds. Canopy spruce are the seed source for future spruce regeneration and thus are critical to retain. When creating gaps near canopy spruce, crews should retain canopy hardwoods touching at least two sides of the canopy spruce to serve as a windbreak. Ideally, crews retain hardwoods to the windward side of the canopy spruce to buffer severe wind. Losing a canopy spruce to windthrow is a serious setback in achieving restoration goals. When in doubt, leave more hardwoods than assumed necessary to protect canopy spruce from wind.

Example of Gap Creation to Protect Canopy Spruce from Windthrow



Protecting canopy spruce is critically important for restoration success. Leave at least two, preferably three, sides of canopy spruce protected by hardwoods.

Create gaps

Canopy gaps are typically created via two methods, mechanical or chemical treatment. Mechanical treatment includes felling or girdling competing hardwoods with a chainsaw, brush cutter, or other equipment. Chemical treatment employs herbicide to cull trees. These treatment methods each have their advantages and disadvantages, described below.

Mechanical treatment

Mechanical treatment is an excellent choice in highly sensitive ecosystems, like those containing rare plants, karst geology, or threatened or endangered species that may be adversely impacted by herbicide. Mechanical treatment can take two forms, felling and girdling. Felling competing hardwoods immediately releases suppressed red spruce. Practitioners should be extremely careful to fell trees away from target spruce. Depending on topography and tree lean, accurate directional felling may be difficult, if not impossible. The operator's ability to fell overtopping hardwoods away from target spruce will factor into gap delineation. Although felling immediately releases spruce, note that many hardwood species will stump sprout or sucker, including maples and beech. Felling operations are inherently dangerous and should only be completed by highly trained and competent sawyer teams. **Given safety concerns, difficulty in avoiding impacts to target spruce, stump sprouting, and inefficient use of time, felling hardwoods for spruce release is not recommended.**

Alternatively, mechanical treatment can be completed more safely and quickly via girdling. When girdling, practitioners use a chainsaw or hand girdling tool to cut through the tree's bark and cambium, breaking the flow of nutrients in the trunk. Crews should double girdle hardwoods, creating two circumferential cuts stacked atop one another. Double girdling increases the chances of fully severing the trees' cambium and improves girdling effectiveness.

Although attractive for its minimal impact, girdling often results in significantly higher survivorship of hardwoods than chemical treatment. When monitoring units previously released with a girdling treatment, crews found multiple girdled trees still living 6–7 years after treatment. Most trees showed signs of reduced vigor, notably dead limbs, but still had partially intact canopies suppressing targeted spruce. When using a girdling treatment, be mindful that the largest trees will be difficult to cull. Ensure that crews are cutting completely through bark and cambium layers on both girdle cuts. When treating trees with multiple stems, the perimeter of each stem should be fully girdled.

Chemical treatment

Chemical treatment is often the most efficient and effective method of gap creation. The following chemical treatments are designed to reduce herbicide use and reduce potential damage to non-target plants, while maintaining an effective release treatment. Chemical treatment for spruce release is a two-phase process.

Phase one targets understory stems, less than 6" DBH, using a basal bark herbicide application. Basal bark treatments are best done with low-volume backpack sprayers using an oil-based herbicide solution. Many herbicides approved for basal bark application list both basal oil and diesel fuel as an appropriate carrier. Only basal oil should be used as an herbicide carrier, not diesel fuel. Basal oil is specifically formulated for the task and has a dramatically lower risk of unintended negative environmental impacts than diesel. Basal bark application can be done any time of year as long as stems of target species are dry and there is no snow on the ground. After application, basal bark treatment will be visibly effective within two to three weeks. Stems should be completely dead within a month.

Apply basal bark herbicide uniformly around the base of small trees, being careful not to spray non-target plants. © Will Evans/TNC

Phase two is a hack and squirt or stem injection herbicide application on stems larger than 6” DBH. This treatment is ideally completed after results from basal bark treatment are visible, at least one month after phase one. If any small stems were missed or failed to respond to the phase one treatment, phase two presents an opportunity to retreat. Hacks should be made around the bole of the tree, spaced no more than 1” apart, but not so close as to girdle the tree. The tree should have unhacked and intact tissue between each hack. Hacks should be made with a small, sharp hatchet. Proper hacks fully penetrate the bark and enter the cambium. The depth required to penetrate the cambium will vary based on tree species, age, and bark thickness. Hacks should be made parallel to the ground, creating a small pocket capable of holding several milliliters of herbicide solution. Hacks should be made in one single motion. Hacking a tree multiple times in the same place will destroy the tree’s ability to circulate herbicide. If a hack fails to penetrate the cambium or is not level, it needs to be redone. When attempting a hack for a second time, the newly attempted hack should be made above or below the failed hack. Both hacks should still receive herbicide. On multi-stemmed trees, hacks should be made around the bole of each stem.

In our experience, some large trees will not die from just one ring of hacks. For large stems, particularly red maple, add an additional ring of hacks around the root collar of the tree. These additional hacks and corresponding additional herbicide absorption will increase the likelihood of a complete kill (Jackson, 2019).

Hacks are filled with an herbicide solution applied with a squirt bottle. To encourage as much herbicide absorption as possible, the hack should be filled

Two examples of ineffective hacks. The top photo depicts an instance of multiple hacks in the same space, severing tissue needed to transport herbicide. The photo on the right shows angled hacks. These hacks will fail to hold an adequate amount of herbicide. © Will Evans/TNC

Properly spaced and angled hacks penetrate through the outer and inner bark, piercing the cambium. These hacks are horizontal, forming a stable pocket for herbicide to be absorbed by the tree. Herbicide, dyed blue in this picture, should fill the hacks to the point of runoff. © Will Evans/TNC

completely with herbicide, given a few seconds to absorb that herbicide, and then refilled to the point of runoff.

Hack and squirt application is best done during periods of active growth, typically between June and mid-September in the Appalachians. The herbicide label will provide specific application instructions and time-of-year restrictions. In all cases, defer to the herbicide label and follow state, federal, and landowner regulations. After hack and squirt treatment, trees should show signs of decline within a month. Treatment may not take full effect for several months to a year.

Herbicides and concentrations

It is important to use the minimum concentration of herbicide to achieve the desired outcome. Using just enough herbicide to complete the job will reduce risk to non-target plants, reduce the amount of herbicide put into the environment, and reduce herbicide costs. Practitioners should also use the least toxic herbicide capable of achieving the desired result. Practitioners should avoid using higher toxicity herbicides with signal words “warning” or “danger: poison” when possible. Using lower toxicity herbicides will improve safety and lower environmental risk. A limited body of existing research indicates that appropriately diluted glyphosate applications have limited to no impact on fungal and microbial communities in forest soils (Ratcliff et al., 2006). We recommend against using highly soil-mobile herbicides. Some products, such as hexazinone, are designed to move through the soil and be absorbed by tree roots surrounding the application site. Given that spruce-influenced forests support unique fungal communities, likely support unique soil microbiomes, and are often situated in the high-elevation headwaters of many streams, use of soil mobile herbicides is strongly discouraged until additional research on the impacts of these herbicides in spruce forest is completed.

We recommend using aquatic “safe” formulations of chosen herbicides. Spruce communities often occupy the headwaters of many aquatic systems, so surface and groundwater contamination are serious concerns when using herbicide. Selecting herbicides designed to quickly break down in water will help reduce potential environmental risks with no loss in treatment efficacy. When aquatic-safe formulations cannot be used, avoid herbicide use in stream buffers.

Herbicide use may be restricted by state, landowner, or habitat type. may exist. Confirm that your chosen herbicide is approved for the land management plan and by state herbicide regulatory authority before application. Below are the herbicides and concentrations used by the authors for spruce release work in West Virginia. Other herbicides and concentrations may be appropriate and effective for this work. The following list is non-exhaustive and represents only our experience.

Application Method	Trade Name	EPA Number	Chemical Name	Concentration	Dilutant
Basal Bark Application	Garlon 4 Ultra	62719-527	Triclopyr	30%	Basal oil
Hack and Squirt	Roundup Custom	524-343	Glyphosate	75%	Water

Map and report progress

Mapping and reporting restoration work is critical to long-term monitoring for adaptive management. Spatial records of release treatments allow managers to evaluate treatment efficacy, plan future restoration treatments, and monitor forest response. Reporting and mapping ensure that future managers and practitioners can learn from today's work and improve upon it, rather than having to reinvent or relearn proven restoration tactics.

Formal and informal reporting

Your contract or agreement with the landowner will likely specify the types of reporting required. For contracts with federal agencies, this typically includes completion of forms that broadly describe the work. Although these forms are helpful, they often lack space to provide information on key reporting metrics (described in the Key Reporting Metrics section). In addition to these required reports, practitioners should provide detailed informal reports to the landowner. Informal reporting could include guided site visits with the landowner, written reports and maps, or presentations, all of which should detail the key reporting metrics noted in the Create Goals and Strategies section earlier in this guide. Maintaining clear and consistent communication with the landowner is critical to ensure that practitioners are meeting landowner objectives and landowners fully understand on-the-ground conditions, delays, or changes to work plans.

What to map

Mapping gaps will give crews a sense of where they have been and what size and density of gaps they have already created. Mapping gaps should be done during the previously described gap delineation process. Gaps should be mapped based on trees culled, not spruce released. Mapping trees culled will give managers a more accurate sense of gap size.

Dedicated mapping applications like Field Maps or Avenza are extremely useful for creating accurate treatment maps in the field. © Geneva Brown

Key reporting metrics

The following are key reporting metrics that we recommend including in spruce release reporting.

Site goals and strategies

Site goals and strategies, previously described in detail, should be clearly enumerated in all reports. Documenting goals and strategies can explain how crews made in-the-field decisions and may inform future restoration work.

Herbicide use

If herbicide is used in spruce release, provide sufficient details per the state pesticide regulatory agency and land management plan. Practitioners should keep detailed records of herbicide application rates, quantities used, targeted species, application techniques, applicators present, and any spills, accidents, or near misses. These metrics should be included in both reporting to the landowner and any necessary record-keeping by your state's pesticide regulatory agency.

Common problems and potential solutions

Crews will inevitably encounter problems in the field. Problems that slow down work, change release strategies and/or goals, or otherwise alter treatment workflows should be reported. Examples of problems to report include crew member injuries, difficulty in accessing release sites, herbicide ineffectiveness, unusually rainy weather preventing herbicide application, and lack of releasable spruce within a unit. Solutions employed or potential future solutions should also be noted.

Follow-up treatment recommendations

After treating a spruce release unit, your knowledge of local ecological issues and familiarity with the unit will give you unique insight into potential future restoration needs. Future needs could include the following:

- Additional spruce release: If you find that a unit has ample spruce regeneration but lacks a strong midstory cohort of releasable spruce, it may make sense to return to the unit in the future to give the seedling layer time to advance to sapling size.
- Spruce planting: If a unit lacks enough existing canopy spruce or releasable midstory spruce to achieve the restoration target, it may be necessary to plant spruce to quickly change the stand's species composition. Note that planted spruce will take many years to become large enough to warrant release.
- Non-native invasive species (NNIS): Report NNIS populations in a unit to the landowner prior to release work. Release work can increase light to the forest floor and thus accelerate the growth and spread of NNIS. NNIS should be treated before any canopy manipulation is done.
- Other site anomalies can include the unintended presence of cattle on a site; the observed presence of rare, threatened, or endangered species on a site; and poor access road conditions.

INSECTICIDE/HERBICIDE/FUNGICIDE APPLICATION RECORD

TANK SIZE: _____ ACRES/AREA PER TANK: _____ RECORD NUMBER: _____

DATE	FIELD/AREA/GREENHOUSE LOCATION	TOTAL ACRES - AREA TREATED	CROP/VARIETY	R.E.I. HRS.	TARGET PEST

PRODUCT NAME	FORMULATION (50w, 4L, etc.)	EPA REG#	ACTIVE INGREDIENT	AMOUNT PER TANK	NUMBER OF TANKS	TOTAL AMOUNT
					1 2 3 4 5	
					6 7 8 9 10	
					11 12 13 14 15	
					16 17 18 19 20	

TANK SIZE: _____ ACRES/AREA PER TANK: _____ RECORD NUMBER: _____

DATE	FIELD/AREA/GREENHOUSE LOCATION	TOTAL ACRES - AREA TREATED	CROP/VARIETY	R.E.I. HRS.	TARGET PEST

PRODUCT NAME	FORMULATION (50w, 4L, etc.)	EPA REG#	ACTIVE INGREDIENT	AMOUNT PER TANK	NUMBER OF TANKS	TOTAL AMOUNT
					1 2 3 4 5	
					6 7 8 9 10	
					11 12 13 14 15	
					16 17 18 19 20	

Notes: (weather, special equipment, or other factors impacting applications)

Sample herbicide report log, distributed by the West Virginia Department of Agriculture

Crew management

Safety

Crew safety is the top priority on any job site. Ensuring that crew members feel safe, perform work safely, and look out for one another's safety is of utmost importance.

To ensure crew safety during non-commercial release operations, crew leaders and crew members should have proper herbicide and/or chainsaw certification, depending on release technique. Safety is embedded in crew culture; it is the responsibility of everyone on the crew to speak up when something doesn't look, feel, or sound safe. Below are a series of safety best practices relevant to non-commercial spruce release.

General safety best practices include:

- Keep printed directions to nearby hospitals and emergency contacts in the crew vehicle.
- Brief crews on daily safety plans.
- Travel with extra water and food, take breaks throughout the day to eat and hydrate.
- Always travel with a well-stocked first-aid kit and provide proper first-aid training.
- Equip crews with radios and/or satellite communication devices for easy communication in case of emergencies where there is no cell phone service.
- Equip crew vehicles with paper maps and crew tablets or phones with detailed off-line mapping applications.

Best practices for safe herbicide application include:

- Bring a jug of water and soap for washing hands. Wash before eating and prior to departing from treatment area.
- Observe labeling on personal protective equipment (PPE).
- Wear water-resistant boots.
- Bring the appropriate Safety Data Sheets and ensure that the crew is familiar with them.
- Use a generous amount of dye, not only to indicate what's been treated but also to indicate what has become contaminated.
- Avoid treatments within 50' of roads to avoid future dead limbs and snags falling in the road.
- Always wear nitrile gloves and eye protection, even when these precautions are not required by the label.
- Ensure that first-aid kits include an eye wash solution.
- Wear a set of leather gloves on top of the nitrile gloves when doing hack and squirt applications. The leather gloves improve comfort and grip and protect the hand from abrasions, while the nitrile glove below protects the skin from herbicide exposure.
- Carry extra nitrile gloves in the field. Nitrile gloves tear easily, and torn gloves are ineffective.
- Carry extra clean clothing in the crew truck in case crew members spill herbicide on themselves.
- Mix herbicide above a container filled with cat litter or other absorbent material to contain spills. Equip vehicles with spill kits including paper towels, trash bags, and cat litter.
- Thoroughly read herbicide labels for first-aid instructions before using herbicides.
- Ensure that equipment contaminated by herbicide is isolated from clean equipment.
- Ensure that hatchets are properly sharpened every day.
- Check that herbicides are not expired and were mixed recently enough to still be effective.

Best practices for safe chainsaw use:

- Ensure that all crew members and crew leaders have taken a Stop the Bleed course.
- Equip first-aid kits with tourniquets.
- Use proper PPE.
- Properly maintain and sharpen saws daily.
- Pair every sawyer with a dedicated assistant, and rotate roles throughout the day to reduce fatigue.

Training

Crew efficiency, confidence, and trust start with adequate training. Aside from safety and first-aid training tailored to your treatment methodology, crews and crew leaders should be well versed in tree identification for trees with and without leaves, spruce ecology, gap delineation, and mapping applications. Even if crew members are hired based on previous experience and training, crews should always receive additional training on all topics previously covered to ensure that understanding and knowledge are standardized across the crew.

In addition to being trained in skills needed to perform non-commercial spruce release, crews should be trained in a variety of relevant job skills. Crew members are often recent graduates looking to break into the conservation field. Today's field crews are tomorrow's ecologists, foresters, rangers, and biologists. Training opportunities should be tailored to meet crew members' future career goals. Example trainings include chainsaw certification, résumé and interview workshops, informational interviews, project management training, wildfire certification. Professional skill development is an excellent activity to do on days when weather or equipment failure prevent field work.

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Appendix 1: In-field decision tree

In-field decision matrix for spruce release gap creation

Questions for release practitioners	Yes	No
1. Does creating this gap support the chosen release tactic, strategy, and goal?	Proceed to Q2	Re-evaluate which trees to release in accordance with chosen tactics, strategies, and goals.
2. Are the target spruce tall, vigorous, and healthy?	Proceed to Q4	Proceed to Q3
3. Is the entire stand lacking tall, vigorous, and healthy spruce?	This stand may not be suitable for release.	Leave spruce suppressed. Focus release efforts on the highest quality spruce in the stand.
4. Are the target spruce clustered together?	Proceed to Q5	Releasing individual spruce trees won't shift ecosystem dynamics. Search for clustered trees to release.
5. Are the trees in this cluster dog-haired?	Dog-haired stands are not suitable for release. Consider thinning rather than releasing dog-haired stands.	Proceed to Q6
6. Are there enough no-take trees overtopping the target spruce to prevent adequate release?	Either expand the boundaries of the gap to increase sunlight reaching the target spruce OR leave spruce suppressed.	Proceed to Q7
7. Have the boundaries of the gap been clearly delineated?	Proceed to Q8	Continue walking through the stand and clearly define both the target spruce and the hardwoods to cull to avoid gap creep.
8. Is there an appropriate buffer between this gap and previous or future gaps?	Proceed to Q9	Either leave spruce suppressed OR expand an existing gap to release spruce. Reconsider your answer to Q7.
9. Can any canopy spruce within the gap be protected from windthrow on at least two sides without jeopardizing the efficacy of the gap?	Proceed to Q10	Either decrease the size of the gap to ensure that canopy spruce remain protected from windthrow OR leave spruce suppressed.
10. Will you have to cull areas of dense beech brush and/or cull an excessive number of hardwoods to release a small number of spruce in this gap?	This proposed gap has a poor ratio of hardwoods culled to spruce released and is an inefficient use of time. Leave spruce suppressed.	Proceed to Q11
11. Are there any non-native invasive species within the gap?	Treat any and all NNIS within gap boundaries before culling trees.	Proceed to Q12
12. Can you safely create this gap with your chosen culling method?	Create the gap and release spruce!	Address safety concerns and revisit the previous questions as necessary.

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