Red Spruce Technical Advisory Board

Red Spruce Restoration Recommendations

Photo credit: Patrick Cavan Brown, TNC

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Contents

1. Introduction 4

1.1 RSTAB purpose 4

1.2 Overview of RSTAB process 4

1.3 Key notes on terminology 4

1.4 Participant comments on EA 'purpose and need' 5

2. Desired outcomes from restoration activities 5

2.1 Interdisciplinary ecosystem restoration expertise 5

2.2 Desired ecosystem conditions 6

2.3 Initial desired outcomes based on site condition and historic land use 6

2.3.1 Treatments for different site alterations 6

2.4 Long-term monitoring 7

3. Restoration spatial priorities and criteria 7

3.1 Landscape scale prioritization principles and monitoring indicators 7

3.2 Site scale selection criteria and monitoring indicator 10

4. Vegetation Management Methods for Red Spruce Ecosystem Restoration 11

4.1 Overall restoration recommendations 11

4.2 Partnerships' status of planting projects 12

4.3 Planting methods 13

4.4 Partnerships' status of release implementation 18

4.5 Release methods 18

4.5.1 General principles and recommendations 19

4.5.2 Prescriptions with low levels or no ground disturbance 23

4.5.3 Prescriptions with high levels of ground disturbance 24

4.5.4 Monitoring needs and indicators for adaptive management of release approaches 26

5. Impacts of restoration activities 27

5.1 Impacts to landscape-scale diversity 27

5.2 Key species to consider impacts 28

5.3 Watershed hydrology and aquatic habitat benefits of restoring functioning red spruce ecosystems 29

5.4 Impacts on forest soils and water 30

References 32
Appendices 35
Appendix 1. Participants 35
Appendix 2. Dissenting statements 38
Appendix 3. Summary of red spruce future habitat suitability models 40
Appendix 4. Notes on early outcomes of TNC's commercial spruce release projects 46

1. Introduction

1.1 RSTAB purpose

The Red Spruce Technical Advisory Board (RSTAB) was convened and facilitated by The Nature Conservancy (TNC) for the purpose of providing expert opinion and science-informed technical recommendations on red spruce ecosystem restoration methods and potential impacts to help inform the NEPA contractor completing the USFS Region 8 Subregional Red Spruce Restoration Environmental Assessment (EA). The EA, funded and supported by the Southern Appalachian Sub-Region of USFS Region 8, will span National Forests (NF) with red spruce ecosystems including the Cherokee NF, George Washington and Jefferson NF, Nantahala NF, and Pisgah NF, as well as the Monongahela NF in USFS Region 9.

1.2 Overview of RSTAB process

On 27 October 2023 TNC extended an invitation to partners of the Central Appalachian Spruce Restoration Initiative (CASRI) and the Southern Appalachian Spruce Restoration Initiative (SASRI), as well as other federal and state agencies and NGOs from the restoration community with potential interest and expertise in red spruce ecosystem restoration. From the invitation 48 individuals from 29 organizations joined the RSTAB (Appendix 1).

The RSTAB launched in December 2023. Participants provided input on restoration methods with context on desired conditions and spatial priorities, and potential impacts of restoration activities. Participants provided written and verbal input via virtual meetings one-on-one with the facilitator, in small topical groups, and in full group calls, and once in person for subregional meetings in Elkins, WV, and Asheville, NC, in late February 2024. The facilitator synthesized the input into draft recommendations that were reviewed and discussed primarily at the in-person meetings.

A revised draft was reviewed by participants in April 2024 with final resolutions discussed on 16 April 2024. Any written dissenting opinions were presented by 24 May 2024. The final recommendations were given to the USFS on 7 June 2024. Participants are provided in Appendix 1, and any dissenting opinions are provided in Appendix 2. A folder of partner management prescriptions and protocols referenced in this document was also made available to the USFS.

1.3 Key notes on terminology

Unless referencing a specific red spruce plant community, this document uses “red spruce ecosystem” or “red spruce forest” for brevity throughout to reference the breadth of central and southern Appalachians red spruce plant communities as described in chapter 5 of the upcoming book *Red Spruce Ecosystem Ecology and Restoration in the Central and Southern Appalachians*.

Given the differences in red spruce ecosystem condition and the history of partnerships in the central versus the southern Appalachians this document uses “C Apps” and “S Apps” to differentiate forest conditions and partner input and recommendations where relevant.

1.4 Participant comments on EA 'purpose and need'

Overall, participants express a sense of urgency to restore red spruce ecosystems given impending climate change impacts and the years it will take for restoration activities to be realized as desired outcomes. A thorough analysis of "No Action" in the EA will be important to characterize what the restoration initiatives can provide for ecosystem functions and services. Red spruce ecosystem restoration in the C and S Apps will contribute to enhancing regional biodiversity, long-term carbon sequestration, and water storage capacity of high elevation headwater forests. Although restoring reference assemblages of red spruce plant communities is an important target, restoring the tree species component should be part of a holistic ecosystem restoration program, as described in the section on "Desired Ecosystem Conditions".

The EA can support a holistic ecosystem approach to restoration with a thorough environmental baseline assessment emphasizing environmental factors associated with red spruce and fir dominated ecosystems, including soil properties, hydrologic integrity, terrestrial and aquatic habitat and biota. Ideally the assessment will identify and address, where relevant, the extent and causes of ongoing degradation to soils and streams in watersheds within the historic footprint of red spruce ecosystems. The EA can assess existing impacts to the integrity of red spruce ecosystems from dense networks of old logging roads causing hydrologic alteration and sedimentation, including active coal mining within the Forest proclamation boundary.

Defining red spruce ecosystem desired conditions should consider an all-lands perspective, not just conditions within National Forest System boundaries. The goals for health and integrity of red spruce ecosystems at the landscape-scale should help to inform needed actions on the National Forest System, as well as other federal, state and private lands.

2. Desired outcomes from restoration activities

2.1 Interdisciplinary ecosystem restoration expertise

Overall, desired conditions should be informed by future climate change impacts, and climate change ecologists can provide council in assessing how impacts may require adjustments in desired outcomes. Participants stressed the need to include all ecosystem disciplines and expertise when determining desired outcomes, planning for restoration spatial priorities, designing restoration plans, and monitoring for desired outcomes. Experts from silviculture, heritage resources, ecology, hydrology, soils, and wildlife should be involved at the outset to target community, Tribal, and ecosystem restoration goals, even if the restoration tools of the EA only cover silvicultural methods. The following are recommended *examples* of taking an interdisciplinary approach from the outset of restoration planning.

- Heritage staff should understand the locations and nature of restoration activities at the proposal stage for early identification of concerns.
- Ecologists can help understand the relationships between historic land use, current environmental site conditions, and the potential for restoring (planting) and accelerating (release) native plant communities, as well as which restoration activities will result in the desired ecological outcomes.

- Forest hydrologists and aquatic biologists can help identify freshwater restoration needs at the watershed and site scale, and can create efficiencies in restoration implementation.
- Soil scientists can help identify soils with spodic properties for site suitability that are not currently mapped.
- Wildlife specialists can aid in identifying critical corridors for connectivity and designing prescriptions that enhance wildlife habitat value.
- Silviculturists can be involved to help outline prescriptions to get to desired future conditions.

2.2 Desired ecosystem conditions

Reference **plant communities** and **ecosystem dynamics** are thoroughly described in chapters of the upcoming book *Central and Southern Appalachians Red Spruce Ecosystem Ecology and Restoration*. Old-growth uneven-aged conditions would be widespread in unaltered conditions, with single tree or small canopy gap formation dynamics driving patches of regeneration. These forests have varying unique **cool, moist microclimates** with high levels of cloud deposition dependent on elevation, slope gradient, and slope aspect.

Soils within the red spruce ecosystem footprint have been well-described in the C Apps (Nauman et al., 2015; Leonard, 2022) and can be used for restoration prioritization. Less soils research and mapping have been undertaken in the S Apps. Overall, red spruce soils often have high levels of organic material and high water holding capacity. Given these soil conditions and location at the highest elevations, these forests often support rare high elevation nutrient poor fens and ephemeral and persistent headwater streams supporting rare coldwater dependent species.

The animal communities and their habitat conditions have also been well-described (Diggins et al., 2016 and Ford et al., 2004, 2022 for the NFS; Brown et al., 2022 for the Cheat Mountain Salamander; Clipp et al., 2022 for forest bird communities), and will be thoroughly discussed in the upcoming book.

Additionally, CASRI's Restoration Approach also describes restoration scenarios by initial condition which can be helpful in determining desired conditions in the C Apps.

2.3 Initial desired outcomes based on site condition and historic land use

In all cases, the desired outcome of restoration activities is a transition to more natural condition for the specific site, based on reference condition and reasonable accounting for the future climate. Because a full return to reference condition may not be possible, or may take many years, short term success may be assessed by a stand being closer to that site's natural condition or being on a trajectory toward that end.

2.3.1 Treatments for different site alterations

Underplanting in hardwood forests: Jump-start red spruce re-establishment or increase conifer component of a forest along with other associated species to increase forest diversity and their related benefits for ecosystem functions and services.

Planting in open old fields: Reverse arrested succession caused by soil compaction and nutrient depletion from past land use including over-grazing and logging to restore a dynamic forest. Note: not applicable in natural balds.

Planting on legacy mine lands: Mitigate the loss of forest tree and shrub species diversity, reverse arrested succession, and restore ecosystem and watershed services. Legacy mined lands were reclaimed to grasslands and/or seeded with aggressive non-native and exotic grasses and legumes, have heavily compacted, such that they often lack woody vegetation even decades after reclamation.

Planting in riparian and floodplain corridors and around natural and created wetlands: Stabilize streambanks where erosion threatens the integrity of streams and contributes to deleterious sedimentation of aquatic habitats. Mitigate the effects of livestock grazing up to the stream and associated erosion. Mitigate the loss of stream shading provided by hemlock prior to mortality due to hemlock wooly adelgid in areas that contain or formerly contained red spruce. Provide wildlife habitat in newly created wetlands on legacy mined lands. Reforest floodplains for habitat connectivity and resiliency.

Understory red spruce release in hardwood forests: In areas with understory red spruce where beech brush or other understory shrubs or trees are impeding spruce saplings from reaching the mid-story, remove competitors around individual and patches of spruce saplings either manually or chemically depending on location.

Canopy red spruce release in hardwood forests: In areas where mid-story red spruce is prevented by hardwood trees from growing into the canopy remove selected overtopping hardwood competitors to release individual or patches of red spruce. Set treated units on a track to reach reference/desired spruce canopy coverage while maintaining localized hardwood biodiversity and wildlife habitat. Removal methods are thoroughly described in Section 4.

Structural complexity in even-aged spruce plantations: Increased snags, downed woody debris, patches of regeneration, and multi-level canopy structure.

2.4 Long-term monitoring

Establishing long-term monitoring of the full range of existing conditions, from sites with limited historic disturbance to restoration sites, will be critical to continuing to define desired conditions. Faculty in Virginia Tech's Department of Forest Resources and Environmental Conservation have proposed establishing long-term plots in collaboration with CASRI and SASRI partners across the C and S Apps to monitor red spruce ecosystem trends to inform management and restoration for desired conditions. Monitoring should include multiple indicators of success for ecosystem targets, not just tree growth outcomes.

3. Restoration spatial priorities and criteria

3.1 Landscape scale prioritization principles and monitoring indicators

P**artner led prioritization initiatives** have been ongoing and will continue to help to inform landscape scale priorities for partners. **CASRI** partners used the Byers et al. (2013) cover map to categorize focal areas to protect and improve structure, release, plant and release, and plant. In recent years **CASRI** partners, led by Donald Brown, have been working to update the opportunity map with additional factors for a prioritization tool that identifies landscape level needs for expanding strongholds, connectivity, and wildlife habitat. The CASRI prioritization tool may be ready by the end of 2024. The **SASRI** restoration plan considers the following areas with a spruce density less than or equal to 25% to be the highest priorities: landscapes >6000'; areas where red spruce existed in the late 19th century but where it was unable to recover conifer cover following logging and fires; and areas generally above 5500' with a mesic aspect. Additional, lower priority areas include sites with a spruce density of less than or equal to 25% that are generally above 5500' with a dry aspect and sites 5000' - 5500' with a mesic aspect. SASRI's Spruce Map hosts historic extent, habitat models, and the prioritization data. During the RSTAB process SASRI partners agreed that areas prioritized based on elevation could shift with latitude and that work is needed to identify priority elevations that may be lower at higher latitude areas such as the Virginia Balsams. Additionally, SASRI partners agreed upon the following factors as spatial priorities: historic extent (Pyle & Schafale, 1988), opportunities to connect patches, upcoming updated northern flying squirrel (NFS) model originally provided by Ford et al. (2015), locations with suitable habitat for restoration targets, opportunities to shade high elevation streams, and opportunities to increase stand diversity. SASRI partners noted two research needs to help refine suitable habitat and improve prioritization: soil indicators of historic presence, and cloud base height shifts with climate change.

Principles:

Historic extent/suitable habitat data can inform landscape scale priorities. For the **C Apps (WV)** the Byers et al. (2013) red spruce cover and Spodosols models are the primary insights on historic extent and suitable habitat. For the **S Apps** SASRI uses suitable habitat maps produced by the USFWS and ecological zones produced by Steve Simon.

Increasing habitat connectivity is a priority when restoration within the historic extent will connect existing patches. North-south landscape connectivity needs for climate migrations are most relevant in the C Apps across the high elevation mountain ranges, and less relevant in the S Apps where the habitat suitability is isolated to disjunct mountain peaks. Local connectivity benefits can be gained upslope-downslope, connecting patches, along ridges or stream corridors or between them. Where relevant, key indicator species such as NFS current locations can be used to determine restoration needs for habitat connectivity to recover populations in current conditions and to expand future habitat and abundance of the species[1].

Climate change impacts on future habitat suitability can inform landscape scale priorities. TNC's Resilient and Connected Lands and Freshwater data can identify climate resilient areas and streams where environments will more likely be buffered from rapid change. Red spruce species level models agree that significant habitat will be lost as higher temps in fall and spring will not favor growth. However, current modeling of future suitable spruce habitat may not be taking into account lower elevation occurrences that existed historically but are

[1] Research led by Virginia Tech will produce a new NFS model to create recommendations for spruce connectivity, including adjustments for climate change.

no longer present. There is a need to update models with information on the historical elevational extent of spruce forests, which are expected to show a larger area of future suitability. See the TACCIMO Summary in S. Apps plan, as well as Appendix 3 for a summary of red spruce climate models highlighting predicted trends and influential model variables. However, the methods of most red spruce species suitable habitat models do not consider local adaptation to climate which provide evidence that some populations will persist, and persist much longer, than contemporary model predictions, and models are built from current extent, not the historic extent which extends across a greater elevation range. In fact, in recent decades red spruce populations in the C Apps have been expanding (Rollins et al., 2010) and recovering growth rates since the Clean Air Act (Mathias et al., 2018). New habitat suitability models need a time series of spatially explicit forecasts based on local adaptations, such as in Capblancq et al. (2023) and Lachmuth et al. (2023) to show where there could be rapid rates of change and impacts to connectivity. Mosher is currently working on updating a red spruce future extent model and can be a future planning resource.

Fir specific considerations: Focus restoration efforts on areas where Canaan fir (*Abies balsamea*) in the C Apps and Fraser fir (*Abies fraseri*) in the S Apps historically occurred and has been reduced or no longer exists. In the **C Apps,** fir is a significant component of red spruce forests in West Virginia sites on Dolly Sods, Canaan Valley, Blister Swamp, and Blister Run, and is thought to have been in Cranesville Swamp (spans WV and MD), and Cranberry Glades. In the **S Apps,** fir dominated the highest elevations, generally above 6200’, and was a regular, often co-dominant, component of spruce-fir forests at 5500’-6200’. Fir-dominated high peaks were most extensive in parts of the Smokies, Blacks, and Balsams, as well as dominating naturally at somewhat lower elevation on Grandfather Mountain and on Mount Rogers in Virginia. Of these, the only occurrences on National Forest lands are in the Blacks, the Balsams, Roan Mountain, and Mount Rogers. However, the vast majority of Fraser fir occurrence was in mixed spruce-fir forests at 5500’-6200’, with much acreage on Pisgah National Forest in the Blacks and Balsams as well as Roan Mountain and the Plott Balsams. In the Balsams, fir dominance was limited to a few knobs. Mature Fraser fir often supports a distinctive epiphytic bryophyte assemblage, with many rare species. The importance of fir to these species is additional impetus to focus on its restoration where needed.

Monitoring indicators: Indicators of landscape-level change for adaptive management could include key **wildlife species** and **vegetation patterns,** and should account for how **climate change** may shift patterns**.** Where relevant, the NFS or ecosystem associated bird species (Clipp, 2022) can be indicator species of functional red spruce and fir forest types at scale. Changes in the distribution of tree stem sizes and species composition[2] can indicate transitions to the desired condition of uneven-aged red spruce forests[3]. Across the Apps near-term monitoring is needed in

[2] FIA data shows increasing abundance of red spruce as forests recover from industrial logging of the early 1900s (Nowacki et al., 2010).
[3] In the S Apps monitoring vegetation changes across variables of historic burning and logging could be helpful in informing restoration actions for desired outcomes. For example, assessing unburned logged

places and populations that we expect to be sensitive to gain insights from drought years and years with extreme temperature changes. Monitoring microclimate changes can help in assessing what suite of local conditions are resilient to regional droughts.

3.2 Site scale selection criteria and monitoring indicator

Criteria within landscape scale focal areas for increased likelihood of success:

Elevation recommendations should not be taken as prescriptive, but as guides and as one variable among others in a decision process. In the **C Apps,** sites >3000' are more likely to be successful, see Nauman et al. (2015) for elevation gradient with red spruce abundance, with the exception of frost pockets and cold air sinks at lower elevations such as in western MD. CASRI partners have been planting red spruce seedlings in western MD at 2,500 ft. and lower very successfully for decades. The MD Forest Service has been planting them in the Savage River watershed, as hemlock replacements after dieback for shading streams, at even lower elevations. In the **S Apps** sites >4200', though with emphasis between 5500' and 6000', are recommended as priorities for restoration. Areas between 4200'-5500' were naturally patchy, with some mixed forests of spruce and hardwoods but mostly larger acreages with no red spruce[4]. These elevations are somewhat lower at the northern end of the S Apps spruce-fir forests. Restoration should be supported by historic evidence of red spruce. Sites <4200' are not recommended due to future climate change impacts with unlikely availability of seed sources as the S Apps is at the lowest edge of the red spruce range.

Topographic position can influence restoration success. In the **C Apps** higher elevations (>3500') are receiving more, and more frequent, precipitation requiring few specific site restraints. In lower elevations avoid sunny, exposed, south-facing slopes. Select cold air drainages, north facing slopes, stream sides, riparian areas, wetlands, etc. In the **S Apps** at highest elevations (>5,500') most topographic positions are suitable. At lower elevations (4200'-5000') more mesic sites on north- or east-facing aspects are preferred, though in highly sheltered landforms other aspects can be suitable on a case-by-case basis.

Prioritize restoration activities around **headwater streams** to increase connectivity of riparian corridors and enhance shading as climate changes.

Avoid areas outside of species occurrence and in the **S Apps** areas with limestone surficial geology and other rare habitats that were not historically spruce influenced. Avoid any impacts to other ecosystems near the ecotone, such as High Elevation Red Oak forests.

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sites to determine whether fir or spruce could be planted in areas where blackberry thickets have replaced Fraser fir, or whether spruce saplings might be released in areas currently dominated by yellow birch. Assess burned logged sites where spruce has not recovered and where planting of spruce and/or removal of some hardwoods may be necessary to restore to a desired condition (often a mixed hardwood-conifer forest). Monitor sites that will inform conditions in which spruce is naturally more competitive over birch.

[4] In S Apps need to better understand site variables where spruce was abundant between 4200'-5500'. Observations of unlogged, unburned forests show these lower elevation areas are patchy rather than an even mix of spruce and hardwoods. More clarity on strategic spatial priorities and the range of desired conditions for these locations is needed on the red spruce ecotone with other common forest types.

Monitoring needs for adaptive management at site/stand scale: We recommend monitoring how climate change may be changing red spruce ecosystem dynamics across a range of elevation and topographic positions to continue to adjust restoration activities to suitable habitats. Natural resource managers need to understand if the environments in which mature red spruce and ecosystem associates can survive are different from plantings and natural regeneration.

4. Vegetation Management Methods for Red Spruce Ecosystem Restoration

4.1 Overall restoration recommendations

RSTAB participants recommend accelerating the pace of plantings to restore or enhance species composition (where appropriate), and emphasize that accelerating canopy release (where appropriate and with appropriate methods) is a priority to accelerate the desired conditions - mature canopy of red spruce and associated species with old growth characteristics - in a timeframe that matters for ensuring the integrity and resilience of the ecosystem in the face of climate change and for its broad suite of ecosystem functions (soil development, water holding capacity, wildlife benefits, micro-climate) and services (climate mitigation, recreation). In some areas, incorporating several terrestrial restoration approaches may be necessary to achieve desired plant community conditions, such as release, underplanting, and direct seeding. And, as noted in section 2.1 and throughout an ecosystem restoration approach that restores overall watershed functions is the desired outcome, not just restoration of the plant species.

CASRI partners **recommend prioritizing hand crews** to accelerate red spruce canopy release on the MNF on ecologically sensitive sites with thick organic soils, steep slopes, and shallow ground water, and in locations without existing road and skid trail access. Ground disturbance in these locations may unnecessarily set back the trajectory of critical soil functions to hold water and sequester carbon, as well as other undesirable impacts to soil biotic communities that influence ecosystem processes. Additionally, partners recommend avoiding ground disturbance where it would impact spruce regeneration, patches of mid-story spruce, and seed trees. Partners recommend considering ground disturbance methods where the impact to ecosystem functions and integrity is limited. Impact avoidance should be prioritized, and mitigation measures should be implemented in areas where impacts are unavoidable. When considering the use of ground disturbance activities, the principal goal should be to achieve the desired ecological outcomes for maintaining existing canopy red spruce, accelerating the growth of midstory red spruce into the canopy, and enhancing overall ecological function of the site.

SASRI partners **do not recommend including restoration activities with ground disturbance (i.e., use of heavy equipment)** on S Apps NFs. This recommendation was agreed upon during the in-person SASRI group meeting where partners had a robust discussion covering the use of ground disturbance to achieve desired restoration goals. Given the marginal opportunity (estimated at 4-10% across S Apps NFs) with little practical opportunity for using ground disturbance on the remote, isolated Sky Islands exists, and the potential ecosystem damage should be avoided. The potential damage from new roads and heavy equipment include new pathways for non-native invasive species in remote locations, significant impacts to rare species, and soil disturbance and erosion in headwaters. Partners recommend using hand crews with mechanical and chemical methods to accelerate red spruce canopy release. No new roads should be built for crews on foot. If any trees are to be removed, such as red spruce for tonewood[5], partners recommend not using heavy equipment, harvesting only on a small scale (<1 ac), use BMPs to address any NNIS issues, and having expert oversight on selection.

SASRI partners recommend that grassy balds which were created from turn-of-the-century logging and fires, and plantations, as opposed to those that occurred pre-European settlement, should be considered for restoration, with sensitivity to how restoration impacts public viewsheds and with sensitivity to existing dedications to historical groups or events.

Fir conservation and restoration considerations: If you are planting or releasing spruce, consider whether fir also needs restoration. In general, it would be appropriate to release existing fir saplings in the same places where spruce is being released. It would also be appropriate to consider planting fir where spruce is being planted in places in areas where the forest would once have been a mix of both species, in the **S Apps** generally above 5500' in mountain ranges that historically supported fir, and in the **C Apps** in the high elevation/low gradient headwater streams and frost pockets. Consider whether there is need/benefit in transplanting rare and characteristic bryophytes and lichens to maturing fir stands.

Cultural resources and considerations: Participants recognize that we have much to learn about regional Tribal Nations and citizens' value of and desire to be engaged in red spruce ecosystem restoration initiatives, or how restoration generated materials could be distributed for traditional use. Some partners are taking steps to engage with Tribal Nations from the region. An intentional plan to include interested indigenous peoples is essential to just, equitable and inclusive restoration initiatives.

4.2 Partnerships' status of planting projects

In the **C Apps** CASRI partners have planted >1.5M red spruce and associated native trees, with annual rates increasing over the past 20+ years (see annual Accomplishment Reports on CASRI website). In 2022, CASRI partners planted 218,337 trees, including red spruce and native hardwoods, conifers, and shrubs, on 474 acres in Central Appalachia. Plantings are largely 1-yr plugs completed by contractors. On the Monongahela NF many of the red spruce plantings have been on reclaimed legacy mined lands and riparian corridors. In Canaan Valley, WV partners have focused on planting in old fields and forest understories. In the **S Apps** SASRI partners have planted >6,000 trees across VA, TN, and NC, and are ramping up production with a newly funded greenhouse to support planting needs. SASRI's focus has been underplanting to re-establish or increase the red spruce component. Plantings are typically completed by SASRI partners and volunteers and are larger 1-gal stock. As SASRI scales up production partners may start to use smaller stock which will likely mean more site prep is needed to address existing veg

[5] Red spruce is a sought after tonewood, or species of wood that have acoustic and aesthetic qualities for wind and stringed instruments. The group noted that the rare exception to the recommendation, small quantities of red spruce removal for tonewood, would be covered under a different NEPA process.

competition. Other planting implementation options are being explored, such as through an agreement with the United Keetoowah Band of Cherokee Indians.

4.3 Planting methods

'Sideboards' for planting: At sites with sufficient natural regeneration and seed trees planting may not needed or appropriate. Sufficient regeneration depends on the desired future conditions, in general >200 understory seedlings per acre may be sufficient. For reference, the northeastern silviculture guide cites 2+ seedlings per milacre as sufficient advance regeneration (Frank & Bjorkbom, 1973).

Seed sourcing: Avoid sourcing from plantations that might contain source genetics from the northern part of the range by assessing historical records, aerial imagery, and conducting critical field surveys. Since 2021 **C Apps** partners have transitioned to using ecological genomics data and climate adaptation science to source from regional red spruce populations with greater genetic diversity to increase the likelihood that the restored trees will be adapted to future climate changes using this app https://fitzlab.shinyapps.io/spruceApp based on Capblancq et al. (2023), Lachmuth et al. (2023) and others from the Keller Ecological Genomics Lab and collaborating research units. CASRI partners recommend including multiple sources over single sources to increase genetic diversity. For Canaan fir sourcing has been a major consideration in fir conservation in WV for 30 years. Currently CASRI aims to protect genetic sources where they currently exist, and diversify sources when introducing fir to a new location. In the **S Apps** partners recommend using sources from within the S Apps region given the strong negative relationships that have been found between transfer distance and fitness traits in red spruce (see Capblancq et al. 2023 and Li et al. 2020). Provisional seed transfer zones (Pike et al., 2020) may be helpful in seedling source selection. Alternatively, moving seed from slightly warmer locations (i.e., lower elevations) to colder locations (i.e., higher elevations, -1 to - 3 degrees C MAT) within the S Apps region would represent assisted population migration and could be beneficial for more resilient forests under ongoing climate change. Overall partners in the S Apps are interested in improving the understanding of red spruce genetic diversity and the range of potential climate adaptive capacity for future restoration. Fraser fir may be genetically more differentiated than spruce and therefore seedling selection should be carefully planned with consultation with geneticists. Partners identified the need to select large fir, potentially old or resistant fir to preserve and for potential cone collection.

Site preparation and post planting needs based on site conditions:

> **Vegetation competition:** Practitioners have dealt with competing vegetation with seedlings planted in clearcuts, tree fall or canopy gaps, and in old fields. In some cases, managers have had to use intensive removal methods with bladed brush cutters or herbicide once per year for the first few years until the seedlings have grown above the competition (e.g., rhododendron, beech brush, blackberry, fern and early successional hardwood species, as well as stump resprouts). In old fields, and extensively in the S Apps, managers have planted larger stock (1 gal pots) to compete with other vegetation.

Soil compaction on old fields: Plantings in old fields without compaction have seen good survivorship. Till or deep rip the ground if the field shows signs of compaction (few if any trees or woody shrubs growing, difficulty putting a shovel into the ground). Cross rip using a large tractor or bulldozer with a single or double ripping shank to achieve soil conditions where tree roots can extend in all directions. Remove invasive species prior to ripping, lest they be spread throughout the project area. If infestation is heavy, mechanically remove, herbicide soon after, and may still need to scrape the topsoil to below the seedbank, ~8 inches to remove the seed source. May need to return for invasive species spot treatments the first few years after planting.

Arrested succession on legacy mined lands: Legacy mined lands refer to sites that were reclaimed post SMCRA with high levels of compaction and cool season non-native grasses and have not naturally succeeded back to forests. CASRI partners, led by Green Forests Work and the MNF, have initiated red spruce restoration of vegetation and wetlands, on 1,444 acres of the Mower Tract legacy mined lands. Site preparation activities are critical for successful reforestation. Soil decompaction is completed in the fall with a large bulldozer pulling one or more 1-m steel ripping shanks promoting water infiltration and root growth for seedlings planted in the spring. For more details about site preparation, see The Forestry Reclamation Approach (Adams et al., 2017) and numerous references on site preparation https://www.osmre.gov/programs/arri/publications.

Forest edge "feathering" can reduce the edge effects between the reclaimed mined area and the native forest. If done prior to planting dozers can create more sheltered areas with downed trees that could also be selected to release spruce on the edge. If feathering, the edge post planting saw crews will minimize any unnecessary disturbance. On legacy mine plantations, partners have needed to knock down exotic or nonnative monoculture plantations, push aside, rip to de-compact the soil, then spread the large woody debris back out over the project area. Downed woody material and root balls from scattered legacy mine plantation trees act as a natural barrier to deer movement, and reduce browsing impacts. Woody material and root balls provide microhabitat that buffers planted seedlings from weather, temperature, and moisture extremes. Tree seedlings planted very close to woody debris piles grow larger and with more vigor. Birds also use debris as perches and spread more species to the restoration areas. Whenever possible, plant seedlings in and adjacent to woody debris piles, and spread any seed in woody debris as well. Odds of survival for all seeded species with woody debris versus without was approximately 2:1 (Branduzzi et al., 2022).

Planting principles supporting survival and growth:

Practitioners in the **C Apps** have seen the greatest success with late winter/**spring plantings**, as soon as the ground has thawed and snow accumulation has melted to <2". Spring plantings have higher success rates for red spruce plugs due to dormancy and reduced risk of transplant shock. Fall plantings, with less time for new root growth to anchor the plant, are susceptible to frost heave, whereby soil water expands when frozen, and pushes planted plugs up and out of the ground. Fall plantings are more susceptible to drought due to low soil saturation compared to spring. Practitioners in the **S Apps** have had success with larger stock able to withstand frost upheaval after **fall plantings**. The seedlings should be watered prior to planting.

Practitioners in the **C Apps** have had the greatest success with **container grown plugs**[6], not bare root stock for red spruce. Considering the cost of planting, and overall survival rates, plugs are far more economical (even if production costs are lower for bare root). Green Forests Work which plants the largest quantities of red spruce have seen 98% survival for red spruce plugs from 3 years of monitoring data. When planting **bare root seedlings** dip roots in a moisture gel, such as Roots' Terra-Sorb, to reduce the risk of roots drying out in planters' tree bags, and to provide seedlings with moisture for the first few days after planting, in case of drought conditions. For **larger red spruce stock** use Super Thrive to help with transplant shock.

Gaps or filtered **light**, and **shelter** from harsh elements are important for seedling growth. When underplanted in full shade red spruce will not grow quickly but can remain in the understory for decades. Planting near logs or rock outcrops and in depressions, which may provide sufficient moisture, has broadly been observed as critical to survival and growth when planted in open areas and high elevations. In open old fields partners have found success with planting white pine as "nurse" trees to provide shade and greater soil moisture to improve survival. Planting in decaying logs has been a successful method to mimic natural regeneration.

Red spruce is shallow-rooted and prefer **moist soils** with thick organic matter, but will persist and are grown on reclaimed former mined soils with little organic matter.

Proper planting techniques include placing the seedling in the ground so that the top of the root collar is level with the ground and not deeper for bare root seedlings, or the top of the soil for plugs or containerized seedlings. Ensure the seedling roots are not excessively trimmed, and that the seedling is planted so that all the roots point down and never curve upwards ("J-rooted"), or come out of the soil. Ensure the planting hole is properly closed and does not have many air pockets.

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[6] Advantages of plugs over bare root seedlings: Containerized plants (plugs) are grown indoors in climate, light/dark controlled greenhouses. Larger seedlings can be produced in a shorter time. The roots are not disturbed upon extraction, which yields a plant that is much easier to plant with much greater first year survival, and much greater first-, second- and third-year growth. This has the advantage of allowing the newly planted tree to out compete surrounding vegetation quickly, and not be overwhelmed by it. To maintain seedling dormancy plugs are shipped frozen and stored in freezers near the planting locations until planting can be arranged providing a wide window of 2+ months to plant. Traditionally produced bare root trees are lifted when site conditions allow, and must quickly be planted or kept in the shade to not dry out. CASRI uses a 15 cubic inch plug, which we have determined is the least expensive size to produce the biggest seedling possible. For projects that need larger plant material, (dense competing vegetation, for example), plug transplants (plug +1, or a plug +2) have been used, but are more expensive and require more out-year planning.

Riparian and wetland sites require specific considerations for success. Plant in higher densities (2’ spacing), with larger (3-4’) containerized stock, to establish cover and habitat more quickly, densely shade water, and stabilize banks. Native speckled alder[7] grows quickly and forms large thickets in just a few years, which is also beneficial wildlife habitat. Live stakes can be stuck in the ground to propagate red osier dogwood, nine bark, willow shrub, and others with great success. Practitioners in the C Apps have seen success planting balsam fir, winterberry holly, wild raisin, arrow wood viburnum, hazelnut, chokecherry, bigtooth and quaking aspen, swamp rose, and red or black elderberry in red spruce ecosystems. Some planting on swamp edges have been less successful. **Transplanting** red spruce plugs < 2’ may be a beneficial strategy for increasing red spruce presence along degraded riparian corridors that have remained open due to historic logging and an overabundance of golden rod, and where commercial practices should not take place due to the close proximity of the stream and potential impacts to aquatic resources[8]. Transplanting achieves multiple goals: improves red spruce habitat connectivity, increases shade on streams to improve coldwater resources for Brook Trout and other important species, and protects soil and water resources by using a non-invasive method.

Underplanting spruce and fir in hardwood forests requires a long term strategy to provide sufficient filtered light for growth. If planting in canopy gaps there must also be a plan to have sufficient funds and capacity to manage vegetation competition. These species are shade tolerant and can persist for years. Target canopy gaps for plantings, or create gaps if possible. Avoid planting in areas with many trees that are not suitable for culling (as noted in release section under leave tree considerations). Prioritize underplanting in older stands where gaps from windthrow or senescence will form sooner compared to younger stands, regardless of further human intervention (returning to mechanically or chemically release underplantings).

Deer and small mammal herbivory can significantly impair growth and survival. Adjust planting rates or avoid planting hardwoods, as noted below, when deer browse pressure is high. Indicators of heavy deer browse are a lack of an understory, or the understory is primarily of invasive species. Use fencing when possible in high pressure areas, especially on open mine lands. If fencing is not possible adjust seedling numbers to overcompensate for potential loss due to herbivory, and plant in protected locations such as adjacent to downed logs and slash as described above. Deer will browse red spruce if food is limited as

[7] Alder and spirea are successional pathways for spruce fir stands in WV and could be sites to target for restoration via planting.

[8] For example, in 2017 crews transplanted seedlings along three tributaries for multiple stream miles on the MNF. Crews dug out red spruce seedlings at a source population on site (typically in densely populated understory on the slope within 100 yards of planting site) and transplanted within 15 minutes along the stream bank in a density of ~1 tree per 6 – 10’. Trees 2’ or shorter had better survival. During initial years (years 1-5 post transplant) the treatment appeared moderately successful. However, upon review of one treatment site in year 7, many red spruce experienced beaver browse, which may be a significant limiting factor to the success of this method without deployment of some sort of beaver deterrent.

sometimes observed in PA and WV. Plant plugs as much as possible, as they are more hardy and resilient to browsing than bare root seedlings. Small mammal browsing, such as rabbits, have also been observed. If beaver activity is nearby the planting may need shift to higher floodplain terraces to accommodate potential effects of current and future dams, and some seedlings may need to be caged to prevent loss.

Planting design and planting rates:

Practitioners do not have much experience with **direct seeding** but do recommend future experimentation as this could be an effective regeneration strategy and have significant cost savings. Direct seeding at 0.1 lbs/ac could occur post-harvest on decommissioned roads and other locations with scarified soil.

Plant in clusters, not rows, **and replant** sites every 10 years to resemble natural red spruce regeneration in gaps, and uneven aged structure.

Practitioners in the **C Apps** generally use the following seedlings per acre ranges, often with 50% red spruce, 50% other native species, based on achieving reference densities. Include fir where it has been lost or could be expanded. Reference red spruce densities for WV averages 185 and ranges ~60-345 per acre (Pauley, 1989; Rhodes, 2022). Reference densities should not be used as prescriptions but as guides in considering the target plant community.

- Legacy mined land grassland plant 680/ac adjusted to 800/ac with heavy deer browsing
- Legacy mined land plantations where trees are knocked down and scattered plant 450/ac adjusted to 700/ac with heavy deer browsing
- Underplanting in a forest plant 275/ac adjusted to 400/ac with heavy deer browsing
- Riparian and upland fields plant 500/ac adjusted to 600+/ac with heavy deer browsing

Monitoring indicators of success, improvements needed, and failure of plantings for adaptive management: Practitioners in the **C Apps** regularly observe **90% or greater survival** of red spruce plug plantings and consider adjustments to management are needed when survival is <50%. Initial slow growth is not a red flag as seedlings progress through the typical “sleep, creep, leap” phases during the first several years; years 1-3 root systems establish, years 3-7 begin growing slowly, and then year 7+ grow much faster, putting on longer leaders each year[9]. Indicators of planted red spruce seedlings’ failure to thrive include needle color changes to orange/rusty (not dulling or yellowing), along with needle loss. Red spruce seedlings can recover from light deer browse with new leaders. See Appendix 4 for CASRI’s planting monitoring protocol. SASRI is currently developing a rapid assessment monitoring protocol.

Fir specific monitoring and research needs:

[9] It is not uncommon, especially on mined lands, to observe significant differences in red spruce seedling heights from the same age cohort. If both are a rich dark green then concern is minimal, it could be differences in soil chemistry or moisture, or browse damage.

- Monitor any planted seedling to gauge browsing pressure/impacts and any needs for fencing or other protection.
- How does seedling collection and poaching impact regenerating stands in S Apps?
- Could transplants from dense seedling stands be used as plantings rather than growing seedlings? What are the costs/benefits? Research into survival rate of transplanted seedlings?

4.4 Partnerships' status of release implementation

C Apps: The first documented herbicide-based red spruce understory release experiment was on 3 red spruce-northern hardwood sites in WV in 2007 as described by Rentch et al. (2016). Release methods included 4 levels of removal by "vertical cylinder projected above the perimeter of the crowns of target red spruce", only the 90% removal treatment was sufficient to accelerate growth. Practitioners in the C Apps have largely agreed that group selection is more effective than single tree release and have shifted practices to larger gap sizes. TNC in WV completes ~500 acres of red spruce release annually with a 4-person crew on the Monongahela NF and other locations. The herbicide active ingredient needed per acre to achieve desired outcomes are well under the maximum usage rates per label restrictions, for example in 2023 to create 22.5 acres of gaps across 500 acres crews used 0.0367 gal/ac Triclopyr (label restriction 1.5 gal/ac/yr) and 0.0759 gal/ac Glyphosate (label restriction 2 gal/ac/yr). TNC in WV monitors leader growth and has found that on average, leaders of spruce trees that received a full canopy release grew more than twice the length of those that were unreleased and roughly 10cm more than trees that received either understory or midstory release treatments (TNC WV spruce release monitoring protocol and results). TNC in MD and VA completed 90 acres on TNC managed lands in 2021-2022. TNC completed 2 commercial sales for red spruce release as described below. WVU, USFS NRS, and the Kumbrabow State Forest have been collaborating on long-term research for commercial release as described below.

S Apps: Partners have completed a variety of release projects with hand crews across the Sky Islands, typically between 10-50 ac. Various methods have been used, but mainly restricted to mechanical methods on the National Forest System as current NEPA does not approve chemical use for red spruce release.

4.5 Release methods

First, we share general principles and recommendations that are broadly relevant to the variety of silvicultural prescriptions that aim to accelerate the release of red spruce from competition and ultimately lead to greater structural complexity and uneven-aged red spruce communities. Next, we provide principles and recommendations specific to approaches that require little, if any ground disturbance, typically completed by crews with hand tools. Release approaches that use ground disturbance (i.e., heavy equipment) are still in the development phase, and only a few participants have had direct experience with designing and implementing these types of prescriptions in research and a few commercial sales in WV. Given the initial outcomes observed we provide principles and recommendations that can mitigate ecosystem impacts from ground disturbance. We provide recommendations on monitoring needs and indicators for both approaches. And finally, we provide notes on early outcomes of TNC's commercial red spruce release projects in WV.

4.5.1 General principles and recommendations

Training and oversight: Regardless the approach the on-the-ground project managers and crews must be well trained in the ecology and sensitivities of high elevation ecosystems, and understand the goals and principles behind the prescriptions. Red spruce release prescriptions require attention to a breadth of sensitive species and careful on-site decision-making that considers the various wildlife benefits of tree characteristics. Clear communication across the typical silos of biologists, silviculturists, tree markers, hand crews or loggers is critical. Breaks in the chain of communication have created undesirable outcomes for many partners.

Site selection: Select sites with reasonable access for crews to minimize disturbance in remote locations and for crew safety. Select sites to improve structure, although this likely requires ground inspection as there is limited spatial data on forest structure. Prioritize even-aged mixed hardwood stands with midstory/sub-canopy red spruce but little to no seed trees and spruce regeneration.

Canopy release considerations: In **C Apps** focal areas where there are extensive opportunities to release understory, midstory and canopy red spruce partners recommend prioritizing full canopy release given greater growth outcomes and ability to achieve the outcomes of red spruce in the canopy with a single entry. In this scenario, spruce >10' are the primary targets for release as releasing spruce <10' will result in a gap that will likely close before the target spruce can reach the canopy. For spruce 10'-30' tall, snag all overstory and midstory stems overtopping the desired gap and up to 50' from any spruce targeted for release. Remove all understory stems that may fill in the gap after release (particularly beech). Remove additional trees to the south, east, west, and uphill of the gap to increase the amount of sunlight reaching the released spruce. If sensitive or desirable trees that cannot be removed are directly overtopping the spruce, do not perform any release actions that may endanger those species. For spruce greater than 30' tall but overtopped by hardwood trees, snag all overstory and midstory stems overtopping the target spruce and stems up to 25' from the targeted spruce, again, without endangering sensitive or desirable trees[10].

Multi-story release considerations: Many partners across C and S Apps include release of understory, midstory, and canopy spruce in the same stand project. One strategy when releasing multi-diameter sized groups of red spruce is to use the 50' diameter gap for all trees in the group, rather than smaller diameter gaps for the smaller diameter red spruce which may close in too soon.

Gap size: Gap sizes vary depending on the extent and density of spruce to be released. In general, partners report that larger gaps are needed to successfully release red spruce and smaller trees need larger gaps so they have a chance at getting to the canopy. In practice the average gap size in treatments in WV is 0.15 ac, with the largest gaps typically ~1 ac (Will Evans, TNC,

[10] For more detailed information see Appendix X for TNC's non-commercial spruce release prescription.

personal communication). Due to shallow root systems, windthrow susceptibility requires leaving support groups of mature spruce residual stands/islands to prevent loss of released red spruce. Exclude equipment from these locations to protect tree roots.

Target canopy cover: Target canopy covers are not meant to be prescriptive but used as guides based on the reference or desired forest conditions. In general, stands with >50-70% red spruce in the canopy may be considered as sufficient for desired conditions and would not be considered a priority for release treatments, unless the stand is even-aged and could benefit from improved structural diversity (e.g., accelerating late successional conditions). In the **C Apps** practitioners generally target prescriptions to achieve 30-50% red spruce (and/or fir) in the canopy, based on minimum canopy cover for NFS habitat suitability (Ford et al., 2004). In the **S Apps** the target canopy cover may be greater based on reference plant communities at the highest elevations.

Fir considerations: Fir may benefit from small (1-5 tree) gaps to increase understory diversity and age class diversity. Research is needed to determine if this would also benefit the bryophyte and lichen communities associated with fir.

Considerations on leave trees

Large diameter, and 'wolf' trees: Prioritize leaving for bat roosting habitat and enhancing older forest characteristics (>20" DBH) which tend to have lots of cracks, crevices and cavities for NFS and other wildlife.

Shaggy bark trees: Prioritize leaving shagbark hickory and "shaggy" bark maples and white oak for nesting material and roosts for bats.

Yellow birch: Yellow birch is valued as a den tree and source of nest material for small mammals and birds, especially large specimens with shaggy bark. Participants across the C and S Apps stressed the need to maintain yellow birch for wildlife use with the understanding that if the species is abundant in the stand it can be culled to release red spruce or fir, but not if limited.

White oak: White oak can look very different at high elevations and be unfamiliar to forestry contractors. Either mark large diameter white oak or provide specific training to avoid losing.

S Apps specific: Also leave mountain ash, heartleaf paper birch, sugar maple, basswood, yellow buckeye, northern red oak, and disease resistant beech and hemlock. Prioritize leaving soft mast species[11].

C Apps specific: Depending on the site, tree species to consider not be culled for spruce release given local rarity, wildlife value, and/or ecological value include red spruce, hemlock, butternut, chestnut, disease resistant beech, hickory, oak, ash, apple, poplar, aspen, hawthorn, black cherry, basswood, serviceberry, hop hornbeam, Frasier magnolia, cucumber magnolia, and any other tree with localized rarity or high wildlife value. Hardwood tree species with

[11] Hard mast species and oak species may favor southern flying squirrel which can out compete and possibly hybridize with NFS and also serve as a vector for deleterious parasites.

high local abundance that can be considered for culling to release spruce are red maple, sugar maple, striped maple, diseased beech, black birch where abundant, and yellow birch where abundant.

Wildlife considerations: In general, leave snags, even in young forests for wildlife habitat.

Cheat Mountain salamander: The WV DNR maintains habitat characteristics to emulate with restoration activities. No release activities should occur in known CMS habitat. No herbicide should be used in CMS areas, only mechanical treatments for competing vegetation. The current protocol for release treatments is to buffer 300' around CMS known habitat and survey restoration activities >3200' to determine probable absence. But, the latest model by Rucker et al. (*in review*) identifies low, medium, and high probabilities that would rule out many locations >3200'. Partners recommend using Rucker's model to reduce unnecessary surveys. Mark and recapture monitoring methods could demonstrate impacts of restoration activities, but is labor intensive.

Northern flying squirrel: As is common for most wildlife species NFS with smaller **home ranges** (i.e., 1-8 ac) indicates they have sufficient habitat conditions and practitioners should avoid heavy equipment and cutting trees. Larger home ranges (i.e., 30-60 ac) indicates poorer habitat and the need for more movement for food and denning resources, and therefore an area that should be considered for restoration. Within larger habitat patches of NFS (i.e., 50 patches in 1000 ac unit) practitioners can have more flexibility with treatments. But use greater caution when designing treatments in areas with small patches (i.e., 5-10 patches in 1000 ac unit), since hardwood den tree removal could impact viability of isolated patches. We recommend that the Section 7 consultation review the above suggestions on habitat size and outline detection periods that could indicate when it is likely there are no NFS present and practitioners can proceed with treatments.

Release prescriptions can improve **habitat conditions**[12] for the NFS in red spruce ecosystems by targeting the following characteristics as outcomes (see also leave tree characteristics above); create snags, leave large diameter trees, leave trees with hollow trunks and cavities, tall overstory, abundant gaps with abundant seedlings and saplings, present midstory, and abundant coarse woody debris. Although the non-native Norway spruce may be targeted for removal in a prescription it should be noted that NFS can also use Norway spruce. NFS have been documented within red spruce monocultures such as plantations, but

[12] Specific to the S Apps, the Carolina northern flying squirrel (CNFS) is primarily associated with mixed northern hardwood-red spruce, red spruce-Fraser fir forested landscapes above 1400m. Studies in western NC demonstrate that CNFS may prefer forest stands with substantial to majority red spruce component. Site occupancy increases where montane conifer (e.g., red spruce) importance values increase from mixed to pure conifer stands. Within conifer dominated stands, CNFS can find habitat features for both foraging and denning, the latter in cavities in the conifers or in dreys constructed among conifer branches. Within mixed stands, CNFS tend to use hardwoods for denning and conifers for foraging and denning. In particular, large hardwoods and snags provide cavities, hollow trunks, and knotholes for denning. In the Great Balsams, squirrels foraged preferentially within stands dominated by red spruce that also contained abundant understory Fraser fir and red spruce advanced regeneration. Foraging was also associated with taller stands (>60') of spruce.

it is not clear if they provide the same benefit as older-aged naturally regenerated red spruce stands, though plantations in many cases are superior to northern hardwoods with few spruce residuals. That said, there is a need to plan for structural and compositional diversity improvements that will build longer term resilience and reduce the risk of blowdown and preserve their habitat.

To protect NFS pups, do not **fell trees** between March 15 - August 31. and look for dreys before **felling trees**. In general, look for and avoid felling trees with dreys or cavities (e.g., old gnarly trees, snags, trees with woodpecker holes or rotted knotholes). Within occupied habitat avoid felling trees >8" DBH, instead use girdling or herbicide ("hack and squirt") if necessary for release of red spruce.

Managers should prioritize **connecting good habitat** patches within historic red spruce ecosystems to realize more outcomes with limited resources per investment. At mid and lower elevations, NFS travel along riparian corridors, especially with hemlock. In S Apps, if mountain peaks are connected by hemlocks and northern hardwoods NFS will traverse to spruce mountain peaks but generally will not cross oak forests. Planting riparian corridors will be key for NFS in both the C and S Apps.

Rock outcrop habitat: Avoid exposing healthy rock outcrop habitat for spruce-fir moss spider and lichens to sunlight with release treatments. If it is a drier site then consider conifer release to improve habitat conditions. To protect spruce-fir moss spider and rock gnome lichen, avoid known populations and buffer potential habitat with no tree removal within at least 50' to protect the outcrop and prevent desiccation.

Rub damage: In the S Apps, when releasing spruce saplings in areas with high potential for damage from wildlife (bear, elk, feral hogs), use chemical or mechanical girdling rather than felling so that the culled hardwood tree remains standing, serving as a barrier around the target spruce tree(s). The standing, girdled hardwoods serve as bollards. Practitioners have noticed more elk rub and hog damage on spruce saplings that were more exposed at the base.

Competing vegetation:

Spruce-fir monocultures may be the desired conditions in some of the highest elevations, but in general, some competing vegetation may lead to overall more diversity.

Beech brush and thick rhododendron patches are common competing vegetation challenges to address. Except for in high priority sites participants recommend avoiding beech brush and thick rhododendron as there are extensive locations to restore without these challenges (with the exception of removing rhododendron from stream banks)[13].

[13] For example, land managers on Grandfather Mountain observed red spruce regeneration success after thinning rhododendron patches back to ~25%/ac on 30 ac project. The team used aerial imagery to identify seed trees and remove rhododendron with chainsaws in a circular buffer. Removed rhododendron was placed in small piles for wildlife habitat.

Non-native and invasive species: Participants emphasizes that NNIS must be treated before, and if needed, after any release treatments.

Aquatic habitat conservation and restoration intersections: Prioritize using a "chop and drop" method to remove hardwood overstory to directionally fell trees into the stream and floodplain of riparian corridors. Felling of overtopping hardwoods for this purpose can be used to release suppressed spruce, and healthy canopy and midstory spruce trees should be avoided during tree felling activities. Large woody material is critical to the Appalachian stream ecosystem as it provides habitat structure and allows for the accumulation of nutrients which are important to the aquatic foodweb, and due to prior land use many streams are often devoid of large woody material or are in need of large woody material additions. Additionally, adding wood to the general floodplain area increases floodplain roughness and creates suitable nurse logs for red spruce to seedlings to utilize. Sawyers should understand basic hydrologic processes in order to fell trees in a manner that create desired habitat features in the stream below. Additionally, grip hoisting is another noninvasive method that can be used in addition to "chop and drop" to better position the felled trees in the stream and create desired habitat features. This method is preferred as it requires no heavy machinery or herbicide and their associated impacts to soil and water resources. This work has been done by Trout Unlimited and the Monongahela NF and can be studied as such for future implementation in other locations.

4.5.2 Prescriptions with low levels or no ground disturbance

Outside of sensitive ecological areas the majority of partners[14] recommend the use of herbicide over solely mechanical methods given fewer safety concerns (use of chainsaws in remote locations), greater treatment efficacy, and time efficiency. See Appendix 5 for example prescriptions and projects.

Mechanically-based prescription principles

Mechanically-based prescriptions to cull overtopping hardwoods are critical for riparian areas and wetlands, and locations with protections for rare species (e.g., Cheat Mountain salamander). Fall chainsaw girdling has resulted in good hardwood mortality for many partners. For large trees that are difficult to kill with girdling partners recommend limbing lower branches.

Herbicide-based prescription principles

Chemicals: Partners report using both glyphosate and triclopyr for hack and squirt on targeted mid-story and canopy hardwood trees. Some report triclopyr[15] is effective, others have not seen good efficacy and have seen loss of desirable root grafted neighboring trees. Several partners recommend switching to imazapyr[16] given evidence of greater efficacy for

[14] See West Virginia Highlands Conservancy's dissenting statement recommending against the use of herbicide on National Forests.
[15] Some partners use a newer form of triclopyr, Vastlan, which is also approved for aquatics.
[16] Example recommended prescription is 20% Imazapyr for stem injection of 2-3" DBH competitors for spruce release of hardwoods, and >2" rhododendron stems.

stump sprouting, fewer impacts to desired species, and reduced chemical and water quantities compared to glyphosate.

Basal bark vs hack and squirt: Basal bark treatment of trees < 6" DBH has been an effective way to release understory spruce. Avoid basal bark treatments on trees with significant exfoliating and fissured bark, since herbicide can drip down and impact sensitive species in the soil. If moss is not removed from the base of the tree basal bark treatments are likely ineffective or require overspray to be effective. For these reasons several partners recommend only hack and squirt over basal bark treatments.

Aquatic sensitivities: Herbicide treatments near waterbodies, streams, wetlands, springs, or seeps require the proper herbicide that is considered safer for aquatic species, or the treatment should be avoided near these water bodies. High elevation headwaters typical of red spruce forests often have unreliable data on streams and vernal pools (depressions not part of a stream system) which can make planning for herbicide use ahead of time difficult. Use high resolution hillshade data to identify potential ephemeral streams and pools. Use Rodeo (or another aquatic safe formulation of glyphosate) or just mechanical methods in these areas as concentrations could easily build up in areas without (frequent) moving water an impact small amphibian and reptile habitat. If herbicide treatments are used near water long term monitoring should be initiated to assess fate of herbicides on vertebrates and in watersheds and soils.

4.5.3 Prescriptions with high levels of ground disturbance

Note, this section covering ground disturbance is relevant to the C Apps as the S Apps participants have recommended against ground disturbance as a tool for restoration.

To date most release treatments using heavy machinery have been part of commercial sales but there may be scenarios in which heavy machinery is used for forest structural improvements and release in red spruce forests that are not part of commercial sales. **We anticipate that due to the lack of pulp and other small wood markets and the fluctuation in timber prices the use of commercial sales will continue to be limited as a payment mechanism for accomplishing release.** Our recommendations are intended to cover any approaches that result in ground disturbance. Please see Appendix 4 for "Notes on early outcomes of TNC's commercial spruce release projects".

Should managers decide that ground disturbance methods are the best tools to accomplish the desired outcomes participants emphasize that the **treatments should not lose sight of desired conditions.** To achieve restoration objectives and have a project result in a net positive ecological outcome, impacts from commercial spruce release need to be minimized and mitigated for where unavoidable. Operations must be able to maintain the overall (or desired) diversity of native plant species in the overstory, midstory and understory, and a multi-aged stand structure, including scattered over-mature trees, small canopy gaps, a well-established mid-story of red spruce and other hardwoods, an understory dominated by red spruce mixed with other saplings, shrubs, ferns and other herbaceous plants, and abundant snags, den trees and downed wood. These ground disturbing activities should be paired with site mitigation, for example, plantings, treatment of NNIS, and decompaction and outsloping of any unneeded roads. Locations with existing road networks should be the priority, not locations in which the project would need to create new roads. Note that some participants have stated that no new road construction should be allowed for restoration activities. If there are no existing roadbeds (inclusive of any legacy linear features such as old skid roads and trails) sites should be left roadless.

Spruce release using ground disturbance methods requires careful oversight of contractors to achieve ecological objectives and avoid and minimize any unnecessary site impacts. Orientation and big picture communication is critical for success. Preharvest meetings should be mandatory.

Principles and recommendations

Site selection: Avoid areas with steep slopes (>35-40%), shallow ground water, soils susceptible to erosion or compaction, riparian zones and other fragile ecological features. Avoid impacts to viewsheds.

Equipment: Focus the use of heavy equipment on sites with existing access (within 0.25 mi of existing roads), as well as log landings, haul roads and skid trails from previous harvesting operations. When possible, employ loggers with logging equipment suited for conducting the harvest in an ecologically sensitive manner. For example, use cutter with processing head rather than feller bunchers, and chainsaws over heavy equipment when possible. Use forwarder truck instead of a traditional skidding hauler.

Skid/road layout: When roads and trails are determined necessary to achieve desired outcomes design should minimize fragmentation and watershed impacts. Skid trail network layout is more critical than other ecosystems. Road layout should avoid impacts to remnant spruce, their root zones, and aquatic resources. Consider the use of slash mats or corduroying of skid roads to reduce rutting.

Pre-commercial treatments: Consider what pre-commercial treatments of beech brush, invasive plants, and other competing vegetation are needed for commercial success in midstory release.

Protect seed trees: Identify and prioritize protecting seed trees by leaving hardwood circle buffer and not allowing heavy equipment within drip line and not let road pass through.

Reduce spruce/desired species loss: Prescriptions should avoid canopy spruce, prioritize midstory spruce for release, and minimize impacts on thickets of red spruce regeneration when possible, since they are critical components of future uneven-aged forest structure. *In other words, ensure prescriptions, and the likely interpretation and implementation of prescriptions, do not result in the excessive loss of understory and midstory spruce while releasing some spruce to the canopy.* Write the prescription so that felled trees do not take out desired trees, and communicate the intentions of the prescriptions to markers and loggers. Canopy release can be single entry, but midstory will need to be multiple entry and prescriptions need to account for maintaining residual spruce for final desired conditions. *In other words, write prescriptions that will maintain enough spruce in the first entry to achieve the desired conditions by the second or third entry.* For successful growth, midstory and understory red spruce need some filtered sunlight but not so much that spruce will not be outcompeted by other vegetation that can more quickly and efficiently respond. Practitioners have seen that leaving 50 square feet basal area seems to be the ‘exact’ amount. Additional insights on maintaining ‘vigor’ in the stands with multiple entries in red spruce forests are provided by Kenefic et al. (2021) on the ‘science and art’ of mixed wood silviculture.

Stream crossings: If any roads are to be built in the process of red spruce restoration activities, such as for commercial timber harvest where access roads are needed, all permanent stream crossings should be constructed in a way that provides full aquatic organism passage. Temporary stream crossings ideally should allow full aquatic organism passage, but at a minimum should be evaluated for impacts to aquatic species. If a temporary crossing is a barrier, this barrier must be removed upon completion of commercial red spruce release to restore aquatic organism passage. Crossings should be evaluated for aquatic organism passage status by watershed, hydrology, or fisheries personnel.

NNIS: All project should have a stringent monitoring plan and treatment of invasive species. NNIS treatments should take place before any ground disturbance and follow-up monitoring and spot treatments should be required one to two growing seasons after every ground disturbing activity.

4.5.4 Monitoring needs and indicators for adaptive management of release approaches

Needs to improve understanding and alignment with desired ecological goals

- Non-target effects from herbicide use in culling trees to release spruce
- Rate of gap closure, and rate relationship to gap size, to predict needs for additional release of mid-story spruce
- Red spruce regeneration rates near cone-bearing spruce to better understand spruce ability to germinate and succeed in heavily disturbed sites
- Understory herbaceous and hardwood re-growth to assess need for follow up treatment if re-growth prohibits understory spruce regeneration and growth
- The structure and species diversity on the forest floor and in the canopy, not just tree age. Long term should be observing uneven aged structure, complexity, patchiness. Monitor for increase in old forest characteristics, such as coarse woody debris, and improvements in forest floor O horizon thickness.
- Bioacoustics increasingly is being adopted as the most statistically robust technique for monitoring habitat occupancy by NFS over time. Because trees mature slowly, improvements to NFS habitat may not be realized for decades. Thus, the occupancy of the NFS population in a restoration area could be sampled before treatment and then again much later, evaluating changes with respect to the archived pre-treatment survey results. Biologists may continue to monitor nest boxes for NFS as another measure of population health. For example, captures of females and sub-adults and not just males and adults indicates population persistence. Also, both nest box monitoring and bioacoustics monitoring may reveal presence of southern flying squirrels. In the S Apps the southern flying squirrel (SFS) encroachment into Carolina NFS range where it has previously not been documented may reflect impacts of climate change (i.e., warmer winters allowing SFS to move up slope). Carolina NFS are sensitive to a nematode SFS are not sensitive to and SFS presence in Carolina

NFS habitat will increase the potential for transmission as they often use/compete for dens.

Indicators of success

- Herbicide efficacy 80% for hack and squirt
- Spruce growth rate increased: annual leader growth 10-12” (0-1” for failure), tree cores to monitor persistence of growth with any canopy closures, percent spruce in canopy increased
- More red spruce cone producing trees
- Increased red spruce regeneration in gaps (indicator of cone producing trees seed viability)
- Stable or increasing populations of sensitive and at-risk species
- Increasing organic carbon and O horizon thickness as an indicator of increased water retention and other soil functions
- Minimal amounts of windthrow

Indicators of improvements needed

- Low rates NNIS of spread and introduction
- Increasing monocultures in gaps
- Low levels of windthrow

Indicators of failure

- NNIS high rates of spread
- High rates of understory mortality
- High levels of windthrow
- Loss of characteristic red spruce ecosystem herbaceous species
- Appearance and rapid spread of new NNIS

Status: CASRI has a rapid release response monitoring protocol that is currently in use but that only captures leader length outcomes. SASRI has no standard protocol but several partners use protocols to capture indicators such as, leader length, DBH, height, cone production, regen, and soil respiration. Partners from CASRI and SASRI agree that long-term monitoring plots that capture above and below ground data is needed.

5. Impacts of restoration activities

5.1 Impacts to landscape-scale diversity

Impacts to landscape-scale diversity resulting from transition from Northern Hardwoods within the historic red spruce ecosystems to a red spruce plant community. Red spruce, fir, and conifers in general, play a unique role for species diversity and ecosystem functions in the largely deciduous forests of the region. In some instances, red spruce restoration activities may reduce the extent of northern hardwood forests, but the landscape scale benefits to biodiversity, both the red spruce fir vegetation communities and dependent wildlife species, outweighs the loss of some northern hardwood forests.

5.2 Key species to consider impacts

Red spruce ecosystems, across its range, host abundant species of bat and birds, the northern flying squirrel; rare bark epiphytes, lichens and bryophytes; and high elevation salamanders as well as other unique flora and fauna. In the **C Apps** restoration activities should give special consideration to the Cheat Mountain salamander (CMS), and in the **S Apps** rock gnome lichen, spruce-fir moss spider, northern saw-whet owl, red crossbill, and black-capped chickadee.

Rock outcrops: Release treatments that open the canopy and provide too much light could negatively impact habitat and populations of the spruce-fir moss spider and rock gnome lichen.

Epiphytes, lichens and bryophytes: Impact on the abundance and diversity of epiphytes, lichens and bryophytes should be factored into release treatments.

Cheat Mountain salamander

Planting activities: More trees planted will benefit CMS as this species is at the upper limit of elevation and needs shading/canopy cover. Other salamanders are more competitive in non-spruce forests, converting to spruce possibly will enhance CMS populations.

Release activities: Felling (over girdling) which creates more coarse woody debris (especially in plantation with little CWD) can provide immediate cover benefits for CMS and other high elevation salamanders (e.g., Wehrle's, pygmy). Overall long-term benefits for CMS due to increased soil moisture and lower soil pH are likely (Brown et al., 2022) but the short-term impacts are still unknown. Release opens the forest floor to more direct sunlight and drier conditions results in more time underground and less time foraging. Linear habitat fragmentation (e.g., trails) has been shown to negatively impact CMS populations and create more competition with other salamanders (Rucker et al., 2022).

Northern flying squirrel: Majority of the landscape does not have high quality small home ranges indicating there are significant opportunities to improve habitat through planting and release activities. If we do nothing forests will mostly support poor quality 60 ac ranges per 1000 ac, but if partners take actions to restore the landscape will be able to support more higher quality <5 ac ranges per 1000 ac and therefore a higher per area density that would promote the likelihood of long-term viability of NFS.

Planting activities: More trees planted will have long-term benefits for NFS with more den trees and nesting materials, and food sources.

Release activities: Disturbance from release activities during pup season can have negative impacts on the species and should be avoided as noted in the methods. Release activities that fell or cull high quality den trees should be avoided. Instead, release can be accomplished by retaining high quality den trees and girdling lower quality hardwoods lacking den site characteristics (hollow trunks, knotholes, cavities, splits).

Bats: Bats use spruce forests but are not dependent on them. Some species will benefit from the temporary reduction in spatial clutter from release or thinning as well as potential creation of day-roosts in snags. However, none of the threatened, endangered or sensitive bat species in the Appalachians are associated with the red spruce forest (Diggins and Ford 2022, De La Cruz et al. 2023a,b) and should not be considered as impediments or constraints to spruce or fir restoration.

Birds: In general, release activities will have no, or a net positive, effect on birds that prefer and breed in spruce stands. Clipp et al. (2022) is a definitive source describing bird use of spruce in the C Apps. Those species listed as being most abundant and frequent in spruce (e.g., juncos, black-throated greens, red-eyed vireos, etc.) are not habitat specialists, per se, so restoration efforts will likely not significantly impact their populations in either direction. The species that are more spruce obligates and the southern extent of their ranges is limited to the Appalachian spruce forests: red crossbills, Swainson's thrush, hermit thrush, black-capped chickadee, and saw-whet owl. For all of those species, restoration actions may have a net positive impact, especially in the long term, simply through the increase of red spruce cover and increase in stand connectivity. By limiting release treatments to stands with <50% spruce in the canopy (as well as the considerations for other species like squirrels), it avoids immediate potential negative impacts to already established populations of these species. In stands with release activities, the increase in stand/canopy heterogeneity should create a positive response. In fact, Swainson's Thrush has been shown to have a positive response to woody debris cover (cover between 20%-40%) - restoration could contribute to the creation of that cover. Improvements to even-aged spruce monocultures (e.g., plantations) that increase diversity of vegetation structure and composition may benefit ground and shrub-nesting bird species such as Canada warbler, black-throated blue warbler, and veery.

In general, management that benefits NFS will also benefit **saw-whet owl**; preserves cavity trees, large patches of spruce-fir forest with little disturbance (from recreation), and good cover for prey (CWD for mice, voles, shrews).

Increasing red spruce mature trees in the canopy producing seed will be beneficial to the **red crossbill** which feeds on conifer seed.

For the **black-capped chickadee** leave small dead hardwoods standing, even <9" DBH, as they are used for cavity nesters.

5.3 Watershed hydrology and aquatic habitat benefits of restoring functioning red spruce ecosystems

Red spruce ecosystems have direct benefits to aquatic species. The range of red spruce is associated with higher elevations across West Virginia, and similarly, higher elevations promote coldwater conditions for headwater streams (if surrounding forest ecosystems are left intact). Many species in West Virginia are dependent on coldwater conditions for survival, most notably the Eastern brook trout. Eastern brook trout populations have been documented as shrinking in other low elevation streams in West Virginia and even within streams on the Monongahela

National Forest, with no direct link to these declines other than suboptimal stream temperatures from climate change (Upper Cheat River – Watershed Effects Analysis 2021). Other coldwater species that benefit from these conditions include mottled sculpin, blacknose dace, fantail darter, redside dace, mountain redbelly dace, and Cheat minnow among others in West Virginia.

Robust red spruce ecosystems provide dense shade cooling air temperatures along these high elevation streams, buffering coldwater conditions from a changing climate. Conifers in general also create conditions that hold cool air even in peak summer. As red spruce mature and eventually die, they also fall into streams which creates pool habitat features and floodplain connectivity in these stream systems, which is beneficial to aquatic species that inhabit these ecosystems, to overall water quality conditions, and to terrestrial species that benefit from optimal water quality and floodplain connectivity.

Healthy red spruce riparian forests also reduce erosion and sedimentation along streams, creating optimal water quality conditions. These conditions foster healthy high elevation stream ecosystems and also benefit downstream stream segments and receiving streams. While species like Eastern hellbender and candy darter are not specifically coldwater species, they rely on optimal water quality conditions with low amounts of sediment and are often found in cool water ecosystems. Keeping water cold as the weather warms earlier in spring in high elevation stream systems by promoting healthy red spruce ecosystems along riparian areas can help ensure optimal conditions for these sensitive species downstream.

5.4 Impacts on forest soils and water

Release with heavy machinery (such as with commercial release) has the potential to impact soil and water, namely through the creation of skid roads. The impacts include ground water interception, which can increase water temperature and impact coldwater resources, as well as sedimentation to streams. These risks increase depending on soil type, the condition of the forest floor O horizon, underlying geology, and steepness of slopes on site. All of these factors should be considered before moving forward on commercial red spruce release. Cable yarding or helicopter logging may be methods to reduce impacts to soil and water versus traditional commercial logging methods. If skid roads are to be built in the process of red spruce release, and will not be needed again or for a significant amount of time, those implementing the work should consider decompacting and returning the road to the original topography/hillslope to restore groundwater capture and avoid impacts to freshwater resources. No commercial release should take place within 100’ of streams and waterways in order to maintain a healthy riparian buffer.

Restoration impacts to forest carbon cycling: There will be long-term climate mitigation benefits from these slow growing forests. But the immediate benefits to soil health and processes should also be valued as a priority. As conifer cover increases carbon stored in the surface O horizons increases, and increases in the subsoil (podzolization). Over time, the transition from a logged/burned site to red spruce and fir cover will increase soil carbon stored in soils. Soil acidifies with increased conifer cover, which creates competitive advantage for conifers and associated hardwoods of this ecosystem type. Impacts should be considered at the landscape scale, should there be widespread use of ground disturbance there may be significant loss of soil structure and carbon pools that could set back the soil functions for decades. Consideration to impacts on the forest floor soil carbon, and the related ecosystem functions (e.g., soil moisture holding capacity, bulk density, soil structure, water infiltration rates, reduced sedimentation and flooding), during extensive ground disturbance should be a priority in decision making. Ground-disturbing activities are likely to result in both acute and chronic effects to these functions and may off-set potential ecological benefit that result from a primarily vegetation-focused management strategy.

Impacts from planting and from release – no ground disturbance: Impacts from planting are the same as release without ground disturbance, just on a slower timeline than release. Planting and release with foot traffic are likely to have none to minimal negative impacts to soils. Planting on Spodosols and Spodic Dystropepts soils with thick O horizons, or even without the thick O horizon, where there is no spruce currently can reinitiate podzolization and the associated benefits of carbon sequestration.

Impacts from release – ground disturbance: Ground disturbance associated with timber harvest results primarily from constructing skid roads that are created by dozer as well as less intensive but more extensive effects on secondary areas of overland skidding with other equipment. These activities negatively alter hydrology, carbon storage, groundwater storage, soil moisture, and mycorrhizal associations (Hartmann et al., 2012; Jones et al., 2000) and should be minimized by focusing ground disturbance-based restoration of red spruce in areas with lower risk (flatter, drier terrain with thinner layers of organic soil) and incorporating mitigation of ground disturbance such as skid road recontouring (Lloyd et al., 2013).

In mixed hardwood conifer forests removing the hardwoods may result in a temporary loss of ecosystem carbon that may return in ~100 years (Nauman et al., 2015), in part depending on the basal area removed (Ross & Knowles, 2023). Therefore, we recommend prioritizing stands that have low soil carbon and therefore little to lose, and limit this practice where release would damage the forest soils water holding capacity. Thick O horizons are often correlated with high densities of conifers, but not always, and if the density of conifers is high the site is not likely in need of restoration. Recommend where possible to restore spruce with hand crews and without heavy machinery in this scenario otherwise soil carbon may be lost from the system. We encourage determining the thickness of the O horizon to be considered as a part of pre-planning surveys, as well as long-term monitoring of these soil traits.

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Appendices

Appendix 1. Participants

Partner organizations participating in the RSTAB from December 2023 through May 2024. Approval date represents agreement with the RSTAB Red Spruce Restoration Recommendations as indicated by email to facilitator. Dissenting opinions are presented in Appendix 2.

Partner organization	Name, title	Approval date
Appalachian Forest Restoration	**Dave Saville**, Owner	7 June 2024
Appalachian Mountain Joint Venture	**Todd Fearer**, Coordinator	5 June 2024
Appalachian Trail Conservancy	**Matt Drury**, Associate Director of Science and Stewardship	3 June 2024
Friends of the Cheat	**Madison Ball**, Conservation Program Director	3 June 2024
Grandfather Mountain Foundation	**John Caveny**, Director of Conservation and Education	29 May 2024
Green Forests Work	**Anna Branduzzi**, Reforestation Coordinator	29 May 2024
National Forest Foundation	**Rachel Blackburn**, Southern Appalachians Program Coordinator	3 June 2024
Southern Appalachian Highlands Conservancy	**Marquette Crockett**, Highlands of Roan Stewardship Director	3 June 2024
Southern Highlands Reserve	**Kelly Holdbrooks**, Executive Director	7 June 2024
TNC Business Units in the central and southern Appalachians	**Deborah Landau**, Director of Ecological Management in Maryland/DC	28 May 2024
	Todd Miller, Director of Conservation Programs in West Virginia	6 June 2024
	Tal Jacobs, Conservation Forester in Virginia	5 June 2024
	Greg Cooper, Southern Blue Ridge Forest Ecologist, North Carolina	29 May 2024
West Virginia Highlands Conservancy (See Appendix 2)	**Rick Webb**, Board Member	6 May 2024
Virginia Tech	**Corey Green**, Assistant Professor of Forest Biometrics	29 May 2024
West Virginia University	**Jay E. Raymond**, Assistant Professor of Biology	31 May 2024

	James A. Thompson, Professor of Soils and Land Use	29 May 2024
State Divisions of Natural and Wildlife Resources	**Caity Homan**, Wildlife Habitat Biologist, Virginia Department of Wildlife Resources	4 June 2024
	Mike Schafale, Ecologist, North Carolina Natural Heritage Program	29 May 2024
State Divisions of Forestry	**Travis Miller**, Assistant State Forester, WV Division of Forestry	29 May 2024
	Zoe Bergman, Research Program Manager, VA Department of Forestry	12 June 2024
	Jordan Luff, Management Forester, NC Forest Service	3 June 2024
NRCS	**Jim Leonard**, MLRA Soil Survey Leader, NE Regional DSP POC, Morgantown Soil Survey Office, Soil and Plant Science Division, USDA-NRCS	4 June 2024
US Fish and Wildlife Services	**Dawn Washington**, Refuge Manager at Alligator River and Pea Island NWRs (current), Supervisory Wildlife Biologist, Canaan Valley NWR (past)	5 June 2024
	Sue Cameron, Fish and Wildlife Biologist, Ecological Services	3 June 2024
USFS Research Stations	**Melissa Thomas-Van Gundy**, Project Leader, Northern Research Station	3 June 2024
	Danika Mosher, GIS specialist, Eastern forest Environmental Threat Assessment Center	7 June 2024
USGS Cooperative Research Unit Program	**W. Mark Ford**, Unit Leader	30 May 2024
USFS Region 8 Apps Subregion	**Jason A. Rodrigue**, Regional Silviculturist, Region 8 Forest Management	5 June 2024

Additional contributors and participants: **Chris Kelly**, Wildlife Biologist, N.C. Wildlife Resources Commission; **Hugh Bullock**, NRCS Forester in TN; **Matt Fitzpatrick**, Professor & Associate Director for Research at the Appalachian Lab, University of Maryland Center for Environmental Science; **Mike Oliver**, State Forester in TN; **Mike Powell**, Director of Land Management and Stewardship, TNC in WV; **Randy Kesling**, West Virginia Highlands Conservancy Board Member; **Rebekah Reid**, Section 7 Team Lead for the USFWS, Asheville ES Field Office; **Troy Evans**, Vegetation Ecologist, Great Smoky Mountains National Park; **Will Evans**, Ecological Restoration Coordinator, TNC in WV

Appendix 2. Dissenting statements

Statement by the West Virginia Highlands Conservancy

The West Virginia Highlands Conservancy (WVHC) representatives on the RSTAB appreciate the opportunity to take part in the early development of information for use in the USFS Region 8 Subregional Red Spruce Restoration Environmental Assessment (EA). We are encouraged by the dedication and intelligence brought to the red spruce restoration issue by the other RSTAB participants.

The purpose of the RSTAB report is to provide "expert opinion and science-informed technical recommendations on red spruce ecosystem restoration methods and potential impacts to help inform the NEPA contractor." *(Section 1.1)* We want to caution the NEPA contractor concerning several topics included in the report that require additional focus in the EA.

Use of Herbicides and Ecosystem Risk: The RSTAB report describes the use of herbicides to control competing vegetation when planting red spruce and to achieve canopy release. The report states: "Where possible partners recommend the use of herbicides over solely mechanical methods given fewer safety concerns, greater treatment efficiency, and time efficiency." *(Section 4.5.2)* The WVHC does not recommend the use of herbicides in the National Forest.

The report further states that "In the long term it will be critical to assess the fate of herbicides on vertebrates and in watershed and soils." *(Section 4.5.2)* The WVHC contends that the best available scientific information concerning the fate and both direct and indirect effects of herbicides applied in Central and Southern Appalachian red spruce forests needs to be described and evaluated prior to prescribing herbicide use. This issue should be addressed in the EA.

Commercial Timber Harvest: The RSTAB report provides multiple recommendations or prescriptions for achieving red spruce restoration objectives in conjunction with commercial timber harvest. The report acknowledges that "To achieve restoration objectives and have a project result in a net positive ecological outcome, impacts from commercial spruce release need to be minimized and mitigated for where unavoidable." *(Section 4.5.3)* The WVHC is concerned about how prospective ecological outcomes will be characterized, evaluated, and compared in the EA. The benefits of red spruce restoration components of management projects involving commercial timber harvest will need to be weighed against ecosystem damage associated with the timber harvest, including loss of biomass, soil damage, hydrologic alteration, and aquatic ecosystem degradation.

Ecosystem Approach to Restoration: The WVHC supports the RSTAB report's emphasis on the need for "a thorough environmental baseline assessment emphasizing environmental factors associated with spruce-fir ecosystems, including soil properties, hydrologic integrity, terrestrial and aquatic habitat and biota." *(Section 1.3)* The WVHC contends that a baseline assessment, including identification of the extent and causes of ongoing degradation to soils and streams associated with the red spruce ecosystem, is an essential first step if regional red spruce restoration is to be efficient and effective. This type of analysis should properly appear in the EA.

Appendix 3. Summary of red spruce future habitat suitability models

Summary of red spruce future habitat suitability models highlighting influential variables on future predictions. Completed by Danika Mosher (USFS SRS) for the RSTAB recommendations.

Mechanistic v. Empirical	Paper	Goal	Location(s)	Model(s)	Climate Data	Most Influential Variable(s)	Trends and/or Future Prediction
E	Beane and Rentch 2015	Risk assessment using GCMs to model future potential distribution	West Virginia	Maxent	WorldClim 2020, 2050, 2080 UKMO-HADCM3 SRES-A2 and B2	Mean temp of coldest quarter Elevation Min temp of coldest month	A2: Complete loss by 2100 B2: Significant decline from 2050 to 2080, 1/6 area in 2100 compared to base
E	Beane et al. 2013	Model current red spruce habitat along gradients of suitability	West Virginia	Maxent	WorldClim	Max temp of warmest month* Min temp of coldest month Slope percent Mean temp of coldest quarter Mean annual temp Soil type Elevation	N/A
E	Boekschoten 2021	Classification algorithm to identify Spruce-Fir forests to understand forest characteristics through remote sensing	Southern Appalachian Spruce-Fir Forests	Maxent Support Vector Machine classification Random Forest	N/A	Northwest Slopes Not elevation	N/A
E	Dialesandro et al. 2019	1. ID historical extent 1989 - 2018 using supervised classification algorithm 2. Habitat suitability analysis on Sharp's Knob	Monongahela National Forest, West Virginia	Classification Tree Algorithm	MACA 2040	Elevation Slope Number of frost days Number of GDD Annual mean temp Annual mean	1989 - 2001: Initial decline 1989 - 2018: Overall gain 2040: 11% Change from deciduous to red spruce

		3. Forecast extent of red spruce in 2040				precip Distance from roads Soil pH Soil's percent silt Soil's percent sand	
E	Iverson and Prasad 2008	Refined DISTRIB and show through 134 tree species	NE United States	DISTRIB - Regression tree analysis, bagging, and random forest	HadleyCM3, Geophysical Fluid Dynamics Laboratory, Parallel Climate Model SRES - A1fi and B2	N/A	Overall diminish of spruce habitat, cannot assign timeline PCM B2: retains spruce-fir habitat suitability
E	Kosiba et al. 2018	Compare tree rings with climate and acid deposition data to understand the relationship between climatic and environmental variables on growth	NE United States	(Just says they were modeled)	6.3*C Mean temp, 106cm precipitation 1925-2012, 1925-1960, 1960-2012, 1980-2012	Minimum January temp Previous year November heating degree days April GDD Preivious year water year precip Cold degree days	High summer temps good for current growth, bad for subsequent growth Difference from elevation and time periods CDD and WDD have larger impact on physiology than climate-growth metrics
E	McLaughlin et al. 1987	Determine which anthropogeneic factors are involved in the decline of red spruce based on historic trends	Maine, New Hampshire, Vermont, New York, West Virginia, Virginia, North Carolina, Tennessee	Multivariate analysis and multiple regression modeling	Modeled over 1900 to 1940, tested against 1941-1960, 1961-1980	Previous year's growth rate Anomalously warm late summers Anomalously cold early-winters Precipitation in July and August of the previous growing season	Regional rather than local stress impacts decline Radial growth significantly less than predicted based on historic climate relationships

E	Mosher et al. 2020	Assess model performance to project into past and future based on most influential variables	Southern Appalachian Spruce-Fir Forests	Maxent Boosted Regression Random Forest	WorldClim CCSM4 Last Glacial Maximum (22,000 years ago) Mid-Holocene (6,000 years ago) RCPs 4.5 and 8.5 in 2050 and 2070	Mountain ash Annual precipitation Min temp of coldest month Mean temp of wettest quarter Max temp of warmest month Slope Mean temp of driest quarter	Projection of 2070 4.5 shows more habitat withstanding contraction than 2050 8.5 No expansion in the southeast, only into Canada
E	Nowacki and Wendt 2010	Identify and prioritize landscapes where red spruce recovery is more likely to succeed	West Virginia	ANOVA	Daymet (Mean air temp, mean precip, GDD, number of frost days)	Elevation Water availability Mean annual precip GDD	Highest probability of success to be in locations that are currently sparse or altogether absent to reconnect Potentially areas prior to logging - assess reality based on soil alteration
E	Nowacki et al. 2010	Identify environmental drivers of red spruce	Eastern United States	Stepwise logistic regression	PRISM 1961-1990	South: Intercept (scarcity), snowfall*, elevation, relative humidity, precipitation, temperature, percent slope	Yellow birch, Fraser fir, balsam fir, and rhododendro may be site indicators for red spruce restoration Southern stands not as strong of an environmental relationship
E	Potter et al. 2010	Predict potential habitat suitability and if species are able to shift into these areas to avoid extensive genetic variation loss	Southern and Central Appalachians	Multivariate Spatio-Temporal Clustering	Hadley model and Parallel Climate Model A1 and B1 scenarios 2050 and 2100	16 spatial environmental variables within the categories of soil, temperature, precipitation, topography, and growing season Hard to discern which variables	Hadley A1: slightly more suitable habitat by 2050, but disappears by 2100

						would cause changes	
E	Stanton 2009	Characterize variables that impact the distribution of red spruce and to project into the future under differenc climate futures	Monongahela National Forest, West Virginia	Maxent	WorldClim HadCM3 Scenario A2 2050 and 2080	Min temp of coldest month Max temp of warmest month Mean temp of warmest quarter Mean diurnal range Precip of driest quarter	Overall diminishment of suitable habitat Suitability shift eastward rather than solely northward
E	Walter et al. 2016	Generate suitability maps for current and future climates for regionally and locally	Central and Southern Appalachians, first-order watershed near Canaan Valley, WV	Decision-tree empirical model to assign probabilities	PRISM 1981-2010 Climate Model Inter-Comparison Project (CMIP-5) RCPs 2.6, 4.5, and 8.5 in 2100	Spodic soils Mean July daily max temps	Based on RCP, Central Appalachians support of spruce likely to decline by 2100 Overall suitable locations will change in RCP 2.6 and 4.5
E	Yetter et al. 2021	Understand climate-growth relationships with spruce in the present and project into the future which will be compared to historic growth	Monongahela National Forest, West Virginia	Regression models	ClimateNA PRISM RCP 4.5 2021-2040, 2041-2060, 2061-2080, 2081-2100 (average growth period 1981-2000)	Historical monthly max temp* Summer max Mean temp in previous year Summer precipitation Moisture index	Higher temperature in fall and spring - more GDD Increased temperature will not favor overall growth

Both	Koo et al. 2011a,b; 2014a,b; 2015	Combine mechanistic (ARIM.SIM) tree growth model to species distribution model (ARIM.HAB) by looking at indirect and direct, and within- and across-scale interactions	Great Smoky Mountains National Park, North Carolina and Tennessee	ARIM.SIM (one main model, eight submodels, Stella) and ARIM.HAB (CART and GLM)	Simulated: 1940-2099 Baseline: 1980-1999 A1B (3.6*C increase in annual mean temp, 3.8*C in winter, 7% increase in annual precip) 10% increase in air pollution, 0%, 10% decrease	Different factors responsible for habitat suitability and growth based on high or lower elevation Air pollution, temperature, precipitation	Overall negative effects of spruce growth for both high and low elevation Higher elevations felt less impacts Spruce growth with 10% decline in pollution High elevation - pollution more of an impact than climate change Growth from 2080 to 2099 in ecotones only
Both	Thomas-Van Gundy and Stuartevant 2014	Simulate if management in Virginia northern flying squirrel habitat (red spruce) is able to meet the landscape-scale restoration goals	West Virginia	LANDIS-II Biomass Succession extension	NOAA NCEI (then NCDC) average min, max, and monthly temperatures MNF Forest Plan for alternative scenarios	Life history traits (longevity, age of maturity, shade tolerance class, effective seeding distance, maximum seeding distance, vegetative reproduction probability and minimum age of vegtative reproduction) Maximum biomass Annual NPP Age-related mortality Soil data (MNF soil pits, soil texture, organic matter content) Climate data	Current practices potentially unsuitable for long-term Protect Spruce scenario has more area with spruce of any age Protect Habitat scenario increases low to moderate suitability for red spruce and thus flying squirrels
M	Laurence et al. 1993	Simulate the interaction of ozone	N/A	TREGO	1, 2, and 10 year simulations	Ozone	Overall reduction of less than 10%

		on growth rates for red spruce						
M	Rentch et al. 2007	Understand existing red spruce resources and assess restoration potential by simulating silvicultural thinning management practice		Central Appalachians	NE-TWIGS growth model Forest Vegetation Simulator (FVS) SUPPOSE	10 year intervals from 2005 to 2106	N/A	Initially more abundant in 10-20 years Less abundant after 50 years Significant total basal area above 1,035 m

Appendix 4. Notes on early outcomes of TNC's commercial spruce release projects

Through a Stewardship Agreement with the MNF, TNC has implemented two commercial sales to advance red spruce composition and structure; red spruce thinning, and group selection for red spruce release. Here is TNC's assessment on early outcomes. Please contact Todd Miller with TNC in WV for more information.

Long-term objectives/desired conditions: A multi-aged stand structure with a high proportion of mature red spruce in the overstory mixed with other hardwood species, scattered over-mature trees, small canopy gaps, a well-established mid-story of red spruce and other hardwoods, an understory dominated by red spruce mixed with other saplings, shrubs, ferns and other herbaceous plants, and abundant snags, den trees and downed wood.

Treatments and observations after initial commercial thinning prescription (2018-21):

- NNIS along adjacent road and understory beech brush pre-treated with herbicide to provide initial release of understory spruce.
- Thinning is often planned as the first of several entries needed to restore a multi-aged stand with a high proportion of red spruce in the overstory.
- Thinning is often intended to avoid creating large gaps (>.25-ac.) in the canopy.
- In addition to uniform thinning over a large area, thinning prescriptions need to select spruce trees for release. Prescriptions such as variable density thinning, single tree selection, crop tree release or shelterwood harvest systems can be adapted to release select, healthy, single or multiple mid-story spruce trees by removing most (but not all) overtopping hardwood trees around trees, leaving some shelter trees to prevent blow-down.
- Post-harvest monitoring indicates that spruce growth has accelerated after even partial release. Concern is that accelerated growth may not continue when canopy gaps are small and may close in before mid-story spruce reach the canopy.

Treatments and observations from initial group selection prescription (implemented along with commercial thinning in 2023):

- Initial removal of most hardwood trees to create canopy gaps and release dense patches of mid-story spruce within group selection areas (ranging from 0.5 - 2 ac) provided full release of those mid-story spruce, with some unavoidable damage to residual stand.
- Impacts on residual mid-story spruce were reduced through careful coordination with operators, careful selection of heavy equipment, directional felling sawtimber trees away from mid-story spruce patches and leaving some sawtimber un-cut where harvesting would cause significant damage.
- Group selection may be suitable in narrow patches of mid-story spruce where overtopping hardwoods can be felled away from spruce trees targeted for release.
- Group selection may be suitable to create gaps next to patches of mid-story spruce by removing commercially valuable hardwoods, achieving some release of adjacent mid-story spruce and creating opening for planting spruce seedlings.

- Within patches of mid-story spruce, non-commercial release by hand crews could be used to create canopy gaps while minimizing impact on residual spruce trees.
- To maximize ecological outcomes and minimize impacts of repeated harvesting operations, heavy equipment could be used in a single entry (instead of multiple entries entailed in some thinning prescriptions) to release mid-story spruce into canopy gaps, and create small openings for planting where there is insufficient spruce regeneration, through the removal of select hardwood sawtimber trees. This single entry could be followed by road decommissioning and decompaction, spruce planting and other activities to restore a multi-aged forest structure dominated by spruce. Repeated beach brush and understory release, as well as overstory gap expansion around mid-story spruce, may also be required but could be accomplished without the use of heavy equipment.
- Importance of tailoring prescription to site conditions (including distribution, density and height of mid-story and understory spruce) to maximize spruce release.

Potential follow-up to improve ecological outcomes:

- Return to thinned areas to expand gaps and release of select mid-story spruce in using non-commercial methods to achieve reference/desired spruce in overstory.
- Decommission/decompact any roads that are not required for future operations.
- Plant spruce in areas deemed appropriate based on presence of Spodosols, light gaps, hydrology and other site conditions.