Chapter 9
History and Accomplishments of Red Spruce Restoration Initiatives Across the Central and Southern Appalachians

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9.1 Restoration Community Responds to an Era of Loss

As detailed in Chap. 1, the extent of red spruce (*Picea rubens*) within the central and southern Appalachians was drastically reduced as a result of logging after European colonization (Fig. 9.1). Red spruce forests were logged extensively from the 1880s to the 1930s, with some areas experiencing subsequent catastrophic wildfires fueled by large amounts of logging slash. On many of these sites, hardwood tree species were more competitive and became the dominant species after logging. Red spruce forests are still recovering from this era of unchecked logging followed by extensive wildfire. Additionally, from the 1960s to the late 1980s, these forests experienced widespread declines from acidic deposition (especially sulfur compounds) and mortality of Fraser fir (*Abies fraseri*) from the introduction of the balsam woolly adelgid (*Adelges piceae*; Eagar and Adams 1992). In 1995, a report to the U.S. National Biological Service (now the Biological Resources Division of the U.S. Geological Survey) stated that the red spruce and spruce-fir forests of the central and southern Appalachians were

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Fig. 9.1 A steam loader on a Shay engine, 1910 (photo by USDA Forest Service)

among the most endangered ecosystems in the U.S. (Noss et al. 1995). With the implementation of air quality standards through the Clean Air Act, the acidic deposition in these high elevation *cloud forests* has declined, reducing stress (Banks 2013; Mathias and Thomas 2018). In recent decades, analysis of inventory data showed increasing red spruce recruitment in the forest understory (Nowacki et al. 2010; Thomas-Van Gundy and Morin 2021), even at lower elevations previously not considered suitable habitat.

The period of broad-scale logging affecting all forests of the eastern U.S. stimulated two general modes of conservation. First, conservationists successfully campaigned for a national park to protect and preserve remaining old-growth forests in perpetuity. Congress authorized the Great Smoky Mountains National Park in 1926 and, after funds were successfully raised and lands acquired, the park was established in 1934. When Great Smoky Mountains National Park was established, about 25% of its area had not yet been logged, including about 17,000 ha (42,000 ac) of forest in which red spruce and spruce-fir were dominant, the largest block of this kind of old-growth forest in the southern Appalachians. Second, among fears that broad-scale logging would impact the future timber supply, the southern Appalachians became the *cradle of scientific forestry* with the founding of the first school of forestry, the Biltmore Forest School, near Asheville, North Carolina in 1896. The USDA Forest Service also began to protect, manage, and restore red spruce forests. Supported in part by the Weeks Act of 1911 the USDA Forest Service became, by far, the largest manager of high elevation red spruce with land acquisitions for the Monongahela NF of West Virginia in 1915, and the acquisitions of the Cherokee (Tennessee), Nantahala and Pisgah (North Carolina), George Washington and Jefferson (Virginia), Chattahoochee (Georgia), and the Sumter (South Carolina) NFs in 1936. These two conservation responses to unsustainable timber harvest were nationally influential in the development of the two dominant conservation value systems (White and Tuttle 2013), for example, National Parks represent the Preservation Ethic, and NFs represent the Resource Conservation Ethic and the mission of forestry schools. This historical context of exploitative timber harvest and legacy of preservation of unlogged red spruce *sky islands* in the Great Smoky Mountains National Park in the southern Appalachians, compared to the more contiguous restoration opportunities from logged and mined red spruce forests across the Monongahela NF in the central Appalachians, contributed to different timelines of SASRI and CASRI partnership formation, as described in the following sections.

Initial red spruce forest restoration work, predominately in the central Appalachians, was facilitated by the Civilian Conservation Corps (CCC) during the 1930s (Fig. 9.2). Beginning around 1928, the USDA Forest Service nursery in Parsons, West Virginia began reducing its production of Norway spruce (*Picea abies*) seedlings and increasing production of red spruce and red pine (*Pinus resinosa*; Fig. 9.3). According to a 1929 planting report for the Monongahela NF, "…red spruce stock from Parsons will be the chief species used" (Robert Whetsell, personal communication). Seed sources for the nursery stock included the Pisgah NF in North Carolina and locations in New Hampshire and Maine. The production of red spruce seedlings soon outpaced that of Norway spruce and was reflected in the plans for seedling production moving into the 1930s. The 1930 spring production plans for the Parsons Nursery anticipated 993,000 red spruce seedlings. The 1935 spring production plan listed the nursery stock on hand as over 7.8 million red spruce, 5.2 million red pine, 1.1 million Norway spruce, and nearly 1 million eastern white pine (*Pinus strobus*) of varying age classes. While the majority of the seedlings produced by the Parsons Nursery were planted on the Monongahela NF, a great number were also shipped to other eastern NFs, such as the Allegheny NF (Pennsylvania) and Pisgah NF (North Carolina), to aid in their reforestation efforts in the late 1920s and much of the 1930s. The CCC were key to the plantings made on the Monongahela NF between 1933 and 1942. Among the earliest CCC plantation work was at Canaan Mountain on the Cheat Ranger District of the Monongahela NF, where they continued reforestation efforts that had begun in 1925. Other locations where the CCC were active in reforestation efforts included Abes Run, Little River, and Laurel Fork on the Greenbrier Ranger District of the Monongahela NF.

Early in its formation, the Monongahela NF did include some high elevation areas that formerly supported red spruce, however, some areas remained in private ownership. For example, a now key landscape for restoration known as the Mower Tract was privately owned and strip mining and logging occurred until it was purchased in 1987 as NF system land. The first Land and Resource Management Plan (Forest Plan) for the Monongahela NF under the National Forest Management Act of 1976 was finalized and implemented in 1986. A species reliant on red spruce-dominated

Fig. 9.2 Civilian conservation corps planting crew in the lower Little River area, Monongahela NF, 1935 (photo by USDA forest service)

forests, the Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*; Fig. 9.4) was listed as federally endangered in 1985 and shaped management of red spruce-dominated forests on the Monongahela NF. Given the lack of information on the species' habitat needs, the general direction was to avoid any areas with overstory red spruce. Much has been learned about the habitat needs of the Virginia northern flying squirrel since then (see Chap. 6), and its federal status has had a large influence on designing active restoration efforts on federal lands, including guides for the amount of canopy red spruce required in an area, as well as for where active restoration may not be appropriate nor necessary.

Targeted efforts to restore former red spruce forest ecosystems in the central and southern Appalachians at scale were significantly advanced with the formation of CASRI in the mid-2000s and SASRI in the 2010s. Partner organizations across both restoration initiatives strive to restore red spruce-dominated communities across administrative boundaries, prioritize restoration efforts, work with partners to obtain funding, and raise public awareness of the unique characteristics of these forests, among other goals.

Fig. 9.3 Women weeding 1-year-old red spruce seedlings at the Parsons, West Virginia nursery in 1940. Women were recruited for this task because of their dexterity (photo by USDA forest service)

9.2 Origins of the Spruce-Fir Restoration Initiatives

Ecoregional restoration initiatives arise in the context of common challenges in defining and implementing the scope and scale of work, but also complex human and organizational dynamics (Adams et al. 2016). Long-term restoration partnerships can wrestle with tensions between restoration goals (e.g., priority places, species, and ecosystem services) and the methods to achieve them (i.e., long-term natural succession versus active management). The continuous need to advocate for staff capacity and funding, and numerous practical issues of logistics to scale on-the-ground impact (e.g., appropriate seed sourcing and weather conditions) can limit success. Maintaining successful individual, organizational, partnership, and stakeholder dynamics within a partnership is complicated by interpersonal to partner-partner and partnership-community trust (Dietsch et al. 2021; Saif et al. 2022), as

Fig. 9.4 A radio-collared Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*) at Mills Run, Pocahontas County, West Virginia (photo by Corinne Diggins)

well as constant leadership changes and shifting priorities. The red spruce restoration initiatives and partnerships that emerged since the early 2000s had elements of many of these factors that have sustained growth and efficacy. Here, we tell the stories of how these restoration initiatives coalesced over several decades around a common vision and succeeded in building momentum despite the challenges. Each was spurred on by the identification of significant conservation concerns and found momentum in collaboration, with the common goal of restoring red spruce ecosystems in the central and southern Appalachians. The partnerships have been maintained by the dedication of individuals across decades from a range of private citizens and restoration businesses, government agencies, non-profit organizations, and universities.

9.2.1 Identification of Spruce-Fir Conservation Issues

Prior to the growing interest in collaborative restoration of red spruce ecosystems, federal and state agencies were beginning to document species losses across the region and the urgency for restoration. Due to the historical loss and limited recovery of red spruce habitat, the Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*), Virginia northern flying squirrel, and Cheat Mountain salamander (*Plethodon nettingi*; Fig. 9.5), all dependent on this ecosystem, were added to the federal list of Threatened and Endangered Species in 1985 (Carolina and Virginia northern flying squirrel) and 1989 (Cheat Mountain salamander). Their listing refocused agency attention on red spruce habitat, and extensive research on their biology and ecological needs was funded by the USDA Forest Service, U.S.

Fig. 9.5 Adult cheat mountain salamander (*Plethodon nettingi*) in a high elevation red spruce (*Picea rubens*) forest in Tucker County, West Virginia (photo by Donald Brown)

Fish and Wildlife Service, and West Virginia Division of Natural Resources. The Virginia northern flying squirrel was delisted in 2008, then re-listed in 2011, and delisted again in 2013. In support of the species recovery plan, researchers and land managers documented individuals and developed habitat suitability models. Many social factors were involved in the change in federal status including the seemingly contradictory idea that a rare species would benefit from active forest management. Recognition of the importance of red spruce forests for this endangered species galvanized action and contributed to partnership formation in both the central and southern Appalachians.

In the early 2000s, the USDA Forest Service Northern Research Station in Parsons, West Virginia added the restoration of red spruce-dominated forests to its 5-year plan of work. Research projects were initiated that addressed silvicultural options and wildlife habitat needs, including the first attempts to predict habitat for the Virginia northern flying squirrel. This was the first time the research lab included restoration of high elevation forests to its formal research portfolio. This paved the way for scientists to be involved in CASRI, continue work on endangered species and active management for restoration, and provide leadership in organizing and publishing the first conference proceedings in 2009 (Rentch and Schuler 2010).

9.2.2 Origins of CASRI—Central Appalachian Spruce Restoration Initiative

The CASRI partnership had its origins in the successful multi-partner Blister Swamp project that restored 20 ha (49 ac) of red spruce wetlands near the Sinks of Gandy in West Virginia from 1999 to 2000 (see Sidebar 9.1). West Virginia University biologists had confirmed that the wetland hosted populations of globally rare and uncommon wildflowers that had been severely impacted by more than 100 years of cattle grazing. The site was privately owned but surrounded by extensive public lands, and therefore represented a critical habitat connectivity barrier and priority for local restoration partners. The Mountain Institute of West Virginia and The Nature Conservancy joined the effort and received a grant from the U.S. Fish and Wildlife Foundation to complete the fence around core areas of the wetlands to save the remaining rare plants. Partners and volunteers completed baseline surveys and planted native trees and shrubs. The Mountain Institute of West Virginia proposed that the federal, state, and non-governmental conservation organizations, who worked collaboratively at Blister Swamp, formalize a partnership to continue protecting and restoring threatened wetlands throughout the state. Then-Monongahela NF Supervisor Clyde Thompson (Fig. 9.6) encouraged the group to envision beyond the protection and restoration of wetlands and consider conservation of all red spruce ecosystems. The U.S. Forest Service committed to expanding the balsam fir (*Abies balsamea*) and Canaan fir (*Abies balsamea* var. *phanerolepis*) seedling planting at Blister Swamp to the public lands downstream. This successful conservation partnership for restoration, founded upon the principles of cooperation and community-based approaches, provided an example to the conservation community. As a result, the High Elevation Conservation Working Group (HECWG) was established around 2006–2007, a precursor of the partnership that would later become CASRI. Conservationists and practitioners focused on building capacity, funding, agency relationships and policies, planning, and other tools to implement restoration at scale. An outreach professional was invited to a working group meeting in 2007 and argued that the unpronounceable acronym HECWG was a barrier to outreach, proposing instead the easier acronym CASRI, for the Central Appalachian Spruce Restoration Initiative, centering the initiative on the ecosystem and not the topography. By 2012, the USDA Forest Service, partners, and volunteers expanded the Blister Swamp restoration efforts to include an adjacent 16 ha (40 ac) on public land, erecting more deer exclosures and planting red spruce and balsam fir seedlings.

Sidebar 9.1 Blister Swamp restoration and the launch of a movement

Blister Swamp, located in Pocahontas County in West Virginia, is one of the last spruce-fir circumneutral wetlands remaining in unglaciated eastern North America, with the calcium-rich water and cool temperatures supporting a rich fen flora characteristic of more northern latitudes (Byers et al. 2010;

Fig. 9.6 Clyde Thompson, retired forest supervisor of the Monongahela NF (Photo by USDA forest service)

Vanderhorst et al. 2012). *Blister* refers to the resin blisters found on the bark of balsam fir trees. West Virginia University (WVU) biologist Roy Clarkson in 1957 wrote “before the turn of the century… Blister Swamp lay serene in the midst of an enormous spruce forest which stretched, at the higher elevations, for many miles in every direction” (Clarkson 1957). By the 1950s conservationists observed that after close to 100 years of cattle grazing in the area the rare plant communities were nearly eliminated (Clarkson 1957; Stephenson and Adams 1986). Beginning in the late 1990s researchers from WVU, West Virginia state agencies, and conservation organizations worked with the private landowners to delineate a 50-acre area for protection and acquired funds to fence and plant locally sourced balsam fir seedlings (Fig. 9.7). Plantings by conservation partners continued into the 2000s, and an additional 40 acres of adjacent public

Fig. 9.7 Blister Swamp restoration site forms the headwaters of the East Fork of the Greenbrier River in Pocahontas County in West Virginia and hosts rare spruce-fir circumneutral wetlands (top). Volunteers construct fences to discourage deer browse of native balsam fir seedlings (*Abies balsamea*) planted within the Blister Swamp exclosure in 2025 (bottom left). Red spruce (*Picea rubens*), planted in 2010, is thriving in the restored wetland margin (bottom right; photos courtesy of Alton and Elizabeth Byers)

lands were fenced and restored. By 2005, the momentum built from collaboration and successes of the Blister Swamp restoration project galvanized the many conservation partners involved to propose formalizing and expanding their restoration efforts, setting in motion the eventual establishment of CASRI as a regional partnership. Red spruce restoration efforts have continued in the area, including an additional 120-acre area fenced and planted with red spruce, balsam fir, and other native species in 2024.

9.2.3 Origins of SASRI—Southern Appalachian Spruce Restoration Initiative

On December 4, 2012, several restoration organizations planned to gather in Asheville, North Carolina to discuss red spruce restoration efforts in the southern Appalachians. What was originally planned to be a meeting of about a dozen people drew over 50 individuals from 15 to 20 organizations. The group discussed everything from red spruce genetics to silvicultural techniques to propagation needs. A member from CASRI also came to the meeting to share their success. At the end of the day, the answer to the question of whether a sister initiative called SASRI should be created was a resounding yes! While the broad participation in the first meeting demonstrated the enormous interest in restoring red spruce, there were three parallel efforts that came together that supported the formation of SASRI: (1) the North Carolina Wildlife Resources Commission, with support from the U.S. Fish and Wildlife Service, had been working to improve and expand habitat for the federally endangered Carolina northern flying squirrel through red spruce planting; (2) the Southern Highlands Reserve—a non-profit organization based in Lake Toxaway, North Carolina—had been working to propagate red spruce for their own property as well as larger restoration efforts; and (3) the Nature Conservancy and the USDA Forest Service were pursuing collaborative efforts to advance restoration of native forests. Specifically, a group of stakeholders on the North Zone of the Cherokee NF had recommended restoration of red spruce forests. The focus of the SASRI partnership is on forests that would be dominated or co-dominated by red spruce, or would have red spruce as a significant component in the overstory, in the absence of anthropogenic disturbance. In areas altered by logging and other disturbances, SASRI endeavors to restore the system to as close to a natural condition as is feasible.

9.3 National Forest Plans Lay the Foundation for Spruce-Fir Restoration Partnerships

In the years leading up to and following the formation of the CASRI and SASRI partnerships, USDA Forest Service-managed lands in the central and southern Appalachians, including the Monongahela NF (West Virginia), George Washington NF (Virginia), Jefferson NF (Virginia), Nantahala-Pisgah NF (North Carolina), and Cherokee NF (Tennessee), had been engaged in planning for restoration of red spruce and spruce-fir communities in their forest plans. Given the large percentage of high elevation forests on USDA Forest Service lands in the regions, this commitment enabled each partnership to meaningfully pursue the goal of restoring red spruce and spruce-fir forests.

Each forest plan addressed the need to maintain and restore red spruce and spruce-fir ecosystems as a critical component of regional biodiversity while generally protecting these ecosystems from conversion to other forest types, thereby setting the trajectory to increasing the extent of future old-growth forests. The forest plans also specified the application of similar management approaches covering natural regeneration, reforestation, and silvicultural prescriptions to enhance current composition and diversity, and to increase the extent of the ecosystem across its historical range. Older forest plans highlighted acid precipitation and balsam woolly adelgid as the current threats, while newer plans added climate change to the list.

The Cherokee NF Land and Resource Management Plan (USDA Forest Service 2004a) is one of the oldest in the region and does not provide vegetation management practices, with the explanation that restoration methods are "not well established." The Plan does address the need to maintain the > 242 ha (600 ac) of historical spruce-fir forests and restore an additional 40 ha (100 ac), excluding natural grassy and heath balds.

The Nantahala and Pisgah NF Land Management Plan (USDA Forest Service 2023) contains geographic area-specific prescriptive language for maintenance and restoration, including the need to develop climate adaptation strategies for the spruce-fir ecosystem currently covering 6,475 ha (16,000 ac) of the forests. The Nantahala and Pisgah NF Land Management Plan supports underplanting and canopy release of red spruce in historical sites, and thinning dense red spruce stands to enhance diversity. The management approaches call out sensitivities to threatened spruce-fir wildlife, such as using hand release of red spruce to create new den trees for the Carolina northern flying squirrel, and maintaining 30 m (100 ft) buffers from rock outcrops with spruce-fir moss spider (*Microhexura monitvaga*; Fig. 9.8) and rock gnome lichen (*Gymnoderma lineare*) habitat.

The Jefferson NF Land and Resource Management Plan (USDA Forest Service 2004b) recognizes 2,353 ha (5,814 ac) of spruce-fir forests primarily on the highest elevation sites of the Crest Zone and Whitetop areas of the Mount Rogers National Recreation Area, with several smaller disjunct populations in other Districts. The Plan identifies at least 469 ha (1,160 ac) across the Forest for red spruce restoration to create habitat corridors and protect rare species, with potentially more restoration opportunities in locations currently in northern hardwood but within the historic red spruce range. The George Washington NF Land and Resource Management Plan (USDA Forest Service 2014) recommends expanding the current 243 ha (600 ac) of

Fig. 9.8 Spruce-fir moss spider (*Microhexura montivaga*) documented on Mt. Mitchell (photo by Gary Peeples)

red spruce to the historical 526 ha (1,300 ac) in the Laurel Fork which is contiguous with spruce-fir forests in the Monongahela NF, and an additional 324 ha (800 ac) currently in northern hardwood. The Plan identifies Norway spruce and red pine plantations as priority locations for restoration.

The Monongahela NF Land and Resource Management Plan (USDA Forest Service 2006) has the most comprehensive guidance and established a new management prescription (i.e., Prescription 4.1: Spruce and Spruce-Hardwood Restoration). National Forest management prescriptions are sub-divisions of the national forest based on a common management emphasis. A management prescription description outlines the management emphasis, current conditions, desired conditions, goals, objectives, standards, and guidelines for resources within the area. Each management prescription also defines spatially where the management prescription is to be applied. Prescription 4.1 aims to conserve red spruce forests at scale, covering 62,160 ha (153,600 ac) for red spruce and northern hardwood forest conservation and restoration. The desired conditions for these areas include a mosaic of red spruce and hardwood forest types largely consisting of multiple age classes at the stand level and an age class distribution across the landscape in this management zone of 60–80% of the red spruce and red spruce-hardwood forests to be late successional stage. The management approaches cover detailed guidelines for reforestation and silvicultural prescriptions.

9.4 CASRI and SASRI Formalize Partnerships

In 2007, CASRI partners, including the U.S. Fish and Wildlife Service, USDA Forest Service, West Virginia Division of Forestry, West Virginia Division of Natural Resources, and The Nature Conservancy, formalized the partnership under a Memorandum of Understanding (MOU) titled “For the Conservation of the Red Spruce-Northern Hardwood Ecosystem.” The MOU set the framework from which the partners could carry out their common vision: “…a broad strategic framework and responsibilities for collaboration…for the long-term conservation of the red spruce-northern hardwood ecosystem in the states of West Virginia and Virginia.” The MOU outlined a strategy for partner coordination, identification of spatial priorities for protection and restoration including core forest buffers and linkages, identification of red spruce-northern hardwood habitat types, and descriptions and implementation of management and restoration activities. To realize the MOU vision, CARSI partners developed a 2010–2020 action plan, organized to fund the work through organizational budgeting, sought government and private funding, and expanded partnerships and capacity. In 2011, CASRI’s Research Committee produced restoration and management guidance detailing how to restore red spruce, including the use of if–then matrices that recommended specific restoration actions based on the range of initial conditions typically encountered in West Virginia (Byers et al. 2011).

By the early 2010s, SASRI partners elevated the need for a southern Appalachian red spruce restoration plan to serve as a guidepost for restoration goals and success.

Development of the plan included mapping existing red spruce extent and partner consensus on criteria for restorable areas. The plan laid out the overarching goal to "…restore red spruce-fir forests in ecologically appropriate locations throughout the Southern Blue Ridge ecoregion" (Medlock 2015). The SASRI partners included four main objectives aimed at building the vision, collaboration, and capacity needed for the scale of restoration. Following the completion of the plan in 2015, the group determined the need to establish a charter reinforcing those objectives, outlining the roles and responsibilities for the steering committee, standing committees, and membership. The SASRI Charter was finalized and adopted in 2016 and amended in 2022 to better address red spruce propagation needs. To address restoration needs SASRI formed *Sky Island* teams covering the Great Smoky Mountains, Plott Balsam Mountains, Great Balsam Mountains, Blacks Mountains, Unaka Mountains, Roan Mountain, Grandfather Mountain, and Grayson Highlands. Partners meet within Sky Island teams to address forest health concerns, develop restoration action and monitoring plans where relevant, and pool resources for management needs.

9.5 Enabling Conditions to Scale Up Science-Informed Restoration

The partnerships' capability to scale up science-informed restoration from inception in the 2000s (CASRI) and 2010s (SASRI) relied on dedication to various types of gatherings, identifying where and what to restore with habitat modeling and restoration prioritization, availability of seedlings to match restoration demand, and a sufficient workforce for plantings and silvicultural treatments.

9.5.1 Galvanizing Gatherings

The CASRI and SASRI partnerships have continued to meet regularly since formalizing the partnerships. The partnerships meet in geographic relevant groupings, such as within Sky Island teams in the southern Appalachians, and in topical sub-committees, such as research, management and monitoring, and education and outreach. Dedication to regular meetings has maintained momentum across decades as funding fluctuates and has enabled the partnerships to maintain focus on the broader vision and goals. Annual partnership conferences, workshops, and field days have fostered shared learning and galvanized new ideas for new initiatives.

The first regional conference was organized in 2009, the "Conference on the Ecology and Management of High-Elevation Forests in the Central and Southern Appalachian Mountains" held at Snowshoe Mountain Resort, West Virginia. The proceedings include 18 peer-reviewed papers and 40 abstracts pertaining to a wide range of topics, such as acid deposition, nutrient cycling, ecological classification, forest dynamics, wildlife, climate change, genetics, and restoration (Rentch and Schuler 2010). The conference included participants and presenters from both the central and southern Appalachians. The emphasis on restoration and practitioners was key. The steering committee sought to create an event where scientists shared their results with managers and managers shared their findings with scientists. While the conference proceedings include the usual scientific papers from designed studies, the conference also included presentations on lessons learned from implementing restoration actions and a panel discussion on building successful partnerships for landscape-scale restoration.

Several additional conferences have been held since 2009, including in 2019 with a focus on new research, virtually in 2020 focused on measuring restoration success, and in 2023 spanning topics covering red spruce soils, mycorrhizal fungi associations, and integrated watershed scale approaches to managing for resilient red spruce forests and cold-water ecosystems. An Appalachians-wide "Red Spruce Climate Change Workshop" was held in Vermont in 2021 to share research perspectives from ecology and natural history, physiology, genetic diversity, local adaptation, seed zones, and applied restoration and silviculture, with the goals of aligning efforts on needed research and practices for climate adaptation for red spruce ecosystems across its geographic distribution. Participants at this workshop were able to set in motion a new collaborative system for sourcing climate-informed red spruce seed for future restoration projects (see Sect. 9.5.3).

9.5.2 Habitat and Restoration Maps Define Need

In the early years of the CASRI partnership, much effort was put to defining the problem, developing messaging, designation of spatial priorities (i.e., core protected areas and buffer areas), and developing annual work plans and annual reports to be used to demonstrate progress. As restoration efforts grew, CASRI partners recognized the need for comprehensive data on potential habitat and restoration opportunities. In 2007, Natural Heritage ecologists at the West Virginia Division of Natural Resources completed a 4-year conservation assessment of the wetlands within the red spruce ecosystem in West Virginia (Byers et al. 2007). The study reinforced the critical importance of high elevation conservation and was followed by a 3-year assessment of upland red spruce ecosystems (Byers et al. 2010), including the first habitat distribution model of the red spruce ecosystem. For the model, split into upland and wetland communities, environmental variables for sites currently supporting red spruce were used to determine potential suitable habitat outside of the sampled areas. The West Virginia Division of Natural Resources used the model to develop a map of current extent, with support from multiple partners including the USDA Forest Service and AmeriCorps, by incorporating thousands of validation points from on-the-ground surveys (Byers et al. 2013). The stand map had a transformative effect on current thinking; although an estimated 90% of red spruce forests had been logged decades ago, 142,583 ha (352,330 ac) of second growth red spruce-dominated forests existed, much more red spruce forest than previously thought. The data was categorized by > 50% "high" cover (21,573 ha [53,308 ac]), 10–50% "medium" cover (74,805 ha [184,848 ac]), trace to 10% "low" cover (46,204 ha [114,174 ac]), and absent within the potential historical range. The suitable habitat model overlain with current cover data on red spruce forests created the first map of restoration opportunities, and this map became a blueprint for CASRI's conservation management activities.

The Canaan Valley National Wildlife Refuge developed spatial models to evaluate locations for planting based on a habitat connectivity-based least cost path analysis, focusing on threatened and endangered species conservation to address potential restoration impacts. Ecologists with the West Virginia Division of Natural Resources Natural Heritage Program developed statewide maps showing areas of high conservation concern based on lists of Species of Greatest Conservation Need from the West Virginia State Wildlife Action Plan (West Virginia Division of Natural Resources 2015).

As a result of the preceding studies and field work, the estimate of the original extent of red spruce in the central Appalachians was now understood to be 404,685 ha (1 million ac), an order of magnitude greater than what remains. With an ambitious vision, CASRI partners could then focus on collaborating for broad-scale impact across ownerships.

In the southern Appalachians, much of the foundational modeling has also been completed to define restoration opportunities for SASRI. Spruce-fir forests have been mapped across much of the southern Appalachians as part of regional ecological zone mapping initiatives (Simon 2011a, b, 2013). SASRI partners, led by the U.S. Fish and Wildlife Service, have produced a map of spruce-fir percent cover in the overstory and understory, and a prioritization scheme based on elevation, red spruce density, and aspect. Elevations > 1,829 m (6,000 ft) on more mesic aspects with < 25% spruce density are priorities for restoration.

9.5.3 Seed Sourcing and Seedling Availability

To achieve reforestation goals, partners needed greater availability of red spruce seedlings. Early efforts in the late 1990s involved transplanting red spruce seedlings from gas pipelines on the Monongahela NF to areas such as The Nature Conservancy's Cranesville Swamp Preserve in Maryland (Fig. 9.9). The Canaan Valley National Wildlife Refuge also partnered with the USDA NRCS Plant Materials Center in West Virginia to store seed and grow red spruce and balsam fir seedlings. To increase the pace and scale of reforestation, partners needed a steady, reliable source of red spruce, balsam fir, and other associated species.

In the late 1990s, a local conservationist and CASRI co-founder, Dave Saville, began collecting balsam fir cones, processing seed, and producing seedlings for habitat restoration projects (Fig. 9.10). Saville collected balsam fir cones from wetlands throughout the West Virginia highlands, avoiding plantations that were

Fig. 9.9 Volunteers collecting red spruce seedlings from gas pipelines on the Monongahela NF in West Virginia to be transplanted to restoration sites such as on The Nature Conservancy's Cranesville Swamp Preserve in Maryland (photo by Deborah Landau)

likely sourced from outside the ecoregion. In the early 2000s, Saville ramped up seedling production by partnering with a Christmas tree grower who collected seed from balsam firs on the Canaan Valley National Wildlife Refuge. Later, Saville began to collect cones and process seeds himself to be shipped to commercial tree growers in the Pacific Northwest and upper Midwest. Growers shipped the seedlings back to Saville who sold them to partners. A continuous source of red spruce seedlings of local origin enabled partners to plan and plant at scale. Saville began in 2000 with approximately 1,000 seedlings, and by 2024 sold 285,000 red spruce and balsam fir to the CASRI partnership for restoration.

In early planting projects, CASRI partners planted red spruce and balsam fir sourced from local populations with the understanding that local environmental adaptations would result in greater survival and growth. This concern evolved within the era of action for climate change impacts. To address climate adaptation concerns, The Nature Conservancy collaborated with Saville and a research group from the University of Maryland and the University of Vermont studying red spruce genetic diversity across the Appalachians. Broadly, the research pointed to low genetic diversity in the central Appalachians (Capblancq et al. 2020), a risk to capacity for climate adaptation. Through a project funded by the Wildlife Conservation Society's Climate

Fig. 9.10 David Saville, local conservationist with CASRI, collecting balsam fir (*Abies balsamea*) cones to produce seedlings for restoration (photo courtesy of David Saville)

Adaptation Fund, the group incorporated insight and values across science, conservation, and practice to source seed from genetically diverse populations to buffer the broader forested landscape of the restoration sites for future climate changes (Prakash et al. 2024). This effort expanded in the following years as more evidence from common garden studies revealed variation in population climate adaptations across the Appalachians and therefore evidence in support of moving seed northward to sites matching predicted future climate (Lachmuth et al. 2024). The CASRI partners now source red spruce seed from populations that will increase genetic diversity, reduce genetic load, and better match future climate adaptation needs of priority restoration landscapes. Practitioners now use mixes of several genotypes to increase the likelihood of restoration success and persistence of the restored forests into the future. In-depth information on climate adaptation considerations is covered in Chap. 7.

In the southern Appalachians, seedlings have been produced since 2008 from local sources by SASRI partners and volunteers supported by the Southern Highlands Reserve. The Southern Highlands Reserve received funding in 2023 to build a larger greenhouse to ramp up production from approximately 1,000 seedling trees annually to at least 50,000 for the coming years.

9.5.4 Sufficient Restoration Workforce

Planting and implementing silvicultural treatments on 100s or 1,000s of acres annually requires a consistent, reliable, and knowledgeable workforce. Ecological restoration goals are often complex, requiring an understanding of the ecosystem (i.e., how trees persist in an environment) not just a single component (i.e., the tree); therefore, treatment prescriptions are often nuanced. Rather than plant trees in rows as in a plantation, trees are planted in clusters to mimic natural regeneration, and near rocks or logs for protection from wind. When using silvicultural treatments to release red spruce trees from midstory competition, the practitioner must know which tree species should not be culled for habitat value, which often varies by location and density of the species. Hiring crews with this type of ecological knowledge is essential to achieving red spruce and spruce-fir restoration goals. CASRI partners have slowly built up their own staff capacity and also rely on volunteers and planting contractors. Future workforce needs remain a key consideration for scaling up restoration efforts.

9.6 Scaling Up Restoration

At the time of this publication, partners have planted well over 2.5 million red spruce and associated native trees and shrubs, and improved spruce-fir forest conditions on estimated 3,200 ha (7,907 ac), primarily across the central Appalachians. Planting projects range from small-scale (approximately 0.5–2 ha [1–5 ac]) volunteer events with school students, community groups, and agency professionals, to large (2–40 ha [5–100 ac] or greater) plantings completed by contractors at landscape scales. Red spruce and associated species have been planted for watershed protection in riparian areas and floodplains, on mountainsides and restored surface mined lands. Red spruce have been planted under existing hardwood forests where soil factors revealed evidence of former red spruce influence (see Chap. 3). Here, we present highlights of partner plantings and canopy release projects from the 2000s to early 2020s.

9.6.1 Scaling up Restoration in the Central Appalachians

By the early 2020s, the CASRI partnership had built an active science-based restoration and monitoring program, supported by a wide range of local scientists and managers with expertise in soils, vegetation, and wildlife. Annual activities include tree plantings, native seed collection and propagation, red spruce canopy release, wetland restoration, monitoring and evaluation, research, education, and outreach. Restoration activities spanned focal areas across the historical footprint, including the Canaan Valley National Wildlife Refuge, Monongahela NF, and state and private lands. Here, we cover a few of the larger restoration projects to highlight how partners have dealt with impaired ecosystem functions, mining impacts, invasive species and other competing vegetation, endangered species, and over-browsing. Restoration projects have historically focused on either planting or release, but projects are increasingly integrating both methods as needed, while seeking to restore the integrated functions for forests and freshwater.

9.6.1.1 Planting-Focused Projects

The Mower Tract Restoration Project in Randolph County and the Sharp Knob Restoration Project in Pocahontas County, both on the Monongahela NF, have restored over 700 ha (1,730 ac) of red spruce ecosystems. The Mower Tract sits atop Cheat Mountain, an 80 km (50 mi) north–south forested corridor in central West Virginia. Cheat Mountain hosts a core remnant of red spruce in the Allegheny Mountains of Appalachia and restoring its integrity at scale has been a restoration priority for partners. Mining and poor restoration practices left the area with large retention ponds, compacted soils, monocultures of non-native trees and grasses, and invasive plants. Project goals were to restore hydrologic function as well as desired red spruce plant communities for wildlife habitat. Between 2011 and 2024, the Monongahela NF and Green Forests Work, in collaboration with nearly 40 partners, have planted over 1 million trees and shrubs, 40% of which were red spruce along with 60 other species, and created over 1,800 wetlands (Fig. 9.11). Practitioners used the Forestry Reclamation Approach (Adams 2017) to remove invasive plant cover and decompact soils with heavy machinery. The project's successes have been a galvanizing force for partners to continue to innovate on restoration methods and build partnerships that are driving restoration in other priority red spruce forests.

Another core remnant of red spruce-fir forests in the Alleghany Mountains sits around and throughout Canaan Valley of West Virginia (Fig. 9.12). This landscape is a complex matrix of intersecting federal, state, and private lands, as well as a popular tourist destination. Forests in Canaan Valley were not heavily impacted by mining, but other historical impacts from logging and burning have resulted in depauperate old fields, unique open red spruce wetland communities, and hardwood forests now dramatically impacted by beech bark disease. Since the 2000s, partners have planted close to 2 million red spruce, balsam fir, and other native plants, primarily on old

Fig. 9.11 Mower tract mined land restoration site with downed plantations of Norway spruce (*Picea abies*), red pine (*Pinus resinosa*), and other woody debris prior to planting native seedlings and wetland creation (photo by Matt Barton, University of Kentucky Agricultural Communications)

fields and underplanting in hardwood forests. Given the high deer browse pressure common in Canaan Valley (30 per km^2 [78 per mi^2]), more emphasis has been placed on red spruce which is less tolerant to deer browsing than other native tree species. The federally threatened Cheat Mountain salamander occurs in the area, which has spurred partners here to examine how restoration practices can avoid impacts to threatened and endangered species.

Smaller planting projects have focused on expanding the red spruce extent in Pennsylvania to replace the conifer functions of dying eastern hemlock (*Tsuga canadensis*) stands, restoring low elevation frost pockets in western Maryland, restoring degraded riparian corridors across the Monongahela NF, and expanding and connecting existing stands in the high elevations of southwestern Virginia.

9.6.1.2 Canopy Release-Focused Projects

Silvicultural prescriptions for the conservation and management of red spruce and spruce-fir forests, such as thinnings, shelterwood harvests, and group selections to benefit advance regeneration, have been extensively researched and documented in its northern range (Frank and Bjorkbom 1973; Dumais and Prévost 2008), but have been

Fig. 9.12 Red spruce (*Picea rubens*) and northern hardwoods in Canaan Valley, West Virginia (photo by David Saville)

largely absent in the central and southern Appalachians. In 2005, researchers in West Virginia initiated one of the first canopy gap release experiments of understory red spruce in northern hardwoods in the central Appalachians to assess growth metrics by a range of gap sizes (Rentch et al. 2016). The study focused on small canopy gaps that would replicate windthrow and other natural disturbances characteristic to red spruce and spruce-fir ecosystem dynamics (see Chap. 5). This study spurred more interest from CASRI partners who continued to refine prescriptions, both mechanical and chemical, and have evolved to include larger gap sizes and group selection, described in detail in Chap. 8. The treatments are implemented by crews on foot and have a low disturbance impact. A crew of four can complete around 200 ha (500 ac) per growing season. Given the extent of restoration potential with existing advance regeneration and the increasing threat of climate change impacts, scaling release treatments at a faster pace has become of interest to CASRI partners. By 2020, some partners began testing new prescriptions for larger scale commercial release of red spruce on the Monongahela NF. At the time of this publication, partners continue to refine commercial prescriptions and monitor outcomes to assess the desired goal of accelerating red spruce to achieve a minimum 30–50% canopy cover, or the relevant canopy cover for the desired conditions.

9.6.1.3 Projects with Multiple Ecological Outcomes and Integrated Methods

The main practices of red spruce restoration are typically aimed at plant community outcomes, either planting new seedlings to expand extent or increasing red spruce and balsam fir canopy cover by removing hardwood competition. But increasingly practitioners are designing projects that aim to restore the integrity of the ecosystem, especially the hydrologic and soil functions. This has been critical where red spruce ecosystems are being restored on former mined lands. The practice of planting seedlings on compacted soils alone would not restore the ecosystem functions in the timescale needed to create a functioning habitat.

9.6.2 Scaling up Restoration in the Southern Appalachians

SASRI's restoration efforts have relied heavily on volunteer support, as opposed to contractors. The first broad-scale collaborative restoration project occurred in 2017 at Flat Laurel Creek in the Great Balsams of North Carolina, a project aimed at improving forest conditions for the endangered Carolina northern flying squirrel and rare bird species such as the red crossbill (*Loxia curvirostra*) and northern saw-whet owl (*Aegolius acadicus*). Partners and volunteers transported red spruce seedlings grown at Southern Highlands Reserve to the project site. Students in Haywood Community College's Forestry and Wildlife programs planted the seedlings and helped the North Carolina Wildlife Resource Commission monitor growth and survival. After this first successful project, SASRI formed S*ky Island* teams in 2018 to facilitate the planning and execution of more projects in each of the mountain massifs in the southern Appalachians. These now include projects on Whitetop, Grandfather, Black, Unaka, Plott Balsam, and Roan Mountains aimed at increasing red spruce and Fraser fir in the understory with plantings, accelerating red spruce to the canopy with gap treatments, increasing stand diversity and structure in red spruce plantations or other unnatural site conditions through the creation of canopy gaps, with concurrent ongoing research on gap size and impacts on red spruce regeneration. Project partners on Roan Mountain are testing planting success across sites impacted by beech bark disease, as well as management methods for reducing damage by elk (*Cervus canadensis*), white-tailed deer (*Odocoileus virginianus*), and feral swine (*Sus scrofa*) on Plott Balsam Mountain.

Funding for restoration in the southern Appalachians increased in the early 2020s, in part due to the 2022 selection of the U.S. Capitol Christmas tree, a red spruce from the Pisgah NF, bringing increased visibility to the ecosystem. In 2023, the USDA Forest Service Collaborative Forest Landscape Restoration Program funded the Pisgah Restoration Initiative for $11 million over 10 years, which will include red spruce restoration for the Black, Roan, Unaka, and Great Balsam *sky islands* (see Fig. 5.3 in Chap. 5). The funds will focus on red spruce cone collection, expanding plantings, and silvicultural treatments for canopy release and recruitment. Restoration activities will restore connectivity of disjunct red spruce patches and build resilience of existing stands to increase structural complexity.

9.7 Conclusions

The CASRI and SASRI partnerships formed and evolved under different geographic and historical contexts, but some of the drivers were similar, including the recognition of unique forest communities and a desire to aid natural processes through active restoration. From this slow accretion of problem identification and partnership building, the work of CASRI and SASRI continues to increase in pace and scale. The partnerships, while formalized in current MOUs, remain fluid and flexible for new partners to be included as needed and for individual agencies, organizations, and private individuals to accomplish their own goals and objectives. The partnership framework is essential for sharing knowledge, lessons learned, funding, and staff and volunteers. The partnerships' continued success will rely on maintaining sustainable levels of funding, adapting to climate change impacts, and dedicated individuals. Although the accomplishments to date are significant, the extent of restoration need, likely greater than 121,000 ha (300,000 ac), across the central and southern Appalachians is still extensive. Red spruce is a slow-growing species and implementing restoration initiatives across administrative boundaries can be challenging, but this landscape-scale perspective is critical for restoring ecosystem structure and function in the central and southern Appalachians.

References

Adams WM, Hodge ID, Macgregor NA et al (2016) Creating restoration landscapes: partnerships in large-scale conservation in the UK. Ecol Soc 21:1

Adams MB (ed) (2017) The forestry reclamation approach: guide to successful reforestation of mined lands. USDA Forest Service Northern Research Station General Technical Report NRS-169, Newtown Square, Pennsylvania

Banks SA (2013) Forest response to the U.S. 1990 Clean Air Act: the southern spruce-fir ecosystem. Thesis, North Carolina State University, Raleigh, North Carolina

Byers EA, Vanderhorst JP, Streets BP (2007) Classification and conservation assessment of high elevation wetland communities in the Allegheny mountains of West Virginia. West Virginia division of natural resources report, Elkins, West Virginia

Byers EA, Vanderhorst JP, Streets BP (2010) Classification and conservation assessment of upland red spruce communities in West Virginia. West Virginia division of natural resources report, Elkins, West Virginia

Byers EA, Cimarolli S, Jones K et al (2011) Central Appalachian Spruce Restoration Initiative (CASRI): restoration approach. Central Appalachian Spruce restoration initiative report, Elkins, West Virginia

Byers EA, Love KC, Haider KR et al (2013) Red spruce (*Picea rubens*) cover in West Virginia, ver 1.0. https://wvgis.wvu.edu/data/dataset.php?ID=455. Accessed 31 Jul 2024

Capblancq T, Butnor JR, Deyoung S et al (2020) Whole-exome sequencing reveals a long-term decline in effective population size of red spruce (*Picea rubens*). Evol Appl 13:2190–2205

Clarkson RB (1957) Blister Swamp, West Virginia. Castanea 22:137–138

Dietsch AM, Wald DM, Stern MJ et al (2021) An understanding of trust, identity, and power can enhance equitable and resilient conservation partnerships and processes. Conserv Sci Pract 3:e421

Dumais D, Prévost M (2008) Ecophysiology and growth of advance red spruce and balsam fir regeneration after partial cutting in yellow birch–conifer stands. Tree Physiol 28:1221–1229

Eagar C, Adams MB (eds) (1992) Ecology and decline of red spruce in the eastern United States. Springer-Verlag, New York, New York

Frank RM, Bjorkbom JC (1973) A silvicultural guide for spruce-fir in the Northeast. USDA forest service northern research station general technical report NE-6, Broomall, Pennsylvania

Lachmuth S, Capblancq T, Prakash A et al (2024) Novel genomic offset metrics integrate local adaptation into habitat suitability forecasts and inform assisted migration. Ecol Monogr 94:e1593

Mathias JM, Thomas RB (2018) Disentangling the effects of acidic air pollution, atmospheric CO_2, and climate change on recent growth of red spruce trees in the central Appalachian mountains. Glob Change Biol 24:3938–3953

Medlock K (ed) (2015) Southern Appalachian spruce restoration plan. https://southernspruce.org/wp-content/uploads/2018/07/final_southern-appalachian-spruce-restoration-plan1.pdf. Accessed 26 Jul 2024

Noss RF, LaRoe ET, Scott JM (1995) Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. U.S. National biological service biological report 28, Washington, DC

Nowacki G, Carr R, Van Dyck M (2010) The current status of red spruce in the eastern United States: distribution, population trends, and environmental drivers. In: Rentch JS, Schuler TM (eds) Proceedings from the conference on the ecology and management of high-elevation forests in the central and southern Appalachian mountains. USDA forest service northern research station general technical report NRS-P-64, Newtown Square, Pennsylvania, pp 140–162

Prakash A, Capblancq T, Shallows K et al (2024). Bringing genomics to the field: an integrative approach to seed sourcing for forest restoration. Appl Plant Sci 12:e11600

Rentch JS, Ford WM, Schuler TS et al (2016) Release of suppressed red spruce using canopy gap creation—ecological restoration in the central Appalachians. Nat Areas J 36:29–37

Rentch JS, Schuler TM (eds) (2010) Proceedings from the conference on the ecology and management of high-elevation forests in the central and southern Appalachian Mountains. USDA forest service Northern research station general technical report NRS-P-64, Newtown Square, Pennsylvania

Saif O, Keane A, Staddon S (2022) Making a case for the consideration of trust, justice, and power in conservation relationships. Conserv Biol 36:e13903

Simon SA (2011a) Ecological zones in the southern Blue Ridge: 3rd approximation. Ecological modeling and fire ecology incorporated report, Asheville, North Carolina

Simon SA (2011b) Ecological Zones on the George Washington National Forest: first approximation mapping. The nature conservancy Virginia field office report, Charlottesville, Virginia

Simon SA (2013) Ecological zones on the Jefferson National Forest study area: first approximation. The Nature Conservancy Virginia Field Office Report, Charlottesville, Virginia

Stephenson SL, Adams HS (1986) An ecological study of balsam fir communities in West Virginia. Bull Torrey Bot Club 113:372–381

Thomas-Van Gundy M, Morin R (2021) Change in montane forests of east-central West Virginia over 250 years. For Ecol Manag 479:118604

USDA Forest Service (2004a) Cherokee National Forest revised land and resource management plan. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5269436.pdf. Accessed 26 Jul 2024

USDA Forest Service (2004b) Jefferson National Forest revised land and resource management plan. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3834582.pdf. Accessed 26 Jul 2024
USDA Forest Service (2006) Monongahela National Forest land and resource management plan. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5330420.pdf. Accessed 26 Jul 2024
USDA Forest Service (2014) George Washington National Forest revised land and resource management plan. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd525098.pdf. Accessed 26 Jul 2024
USDA Forest Service (2023) Nantahala and Pisgah National Forests final land management plan. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd1090063.pdf. Accessed 26 Jul 2024
Vanderhorst J, Byers E, Streets B (2012) Natural heritage vegetation database for West Virginia. Biodiversity & Ecology 4:440
West Virginia Division of Natural Resources (2015) 2015 West Virginia state wildlife action plan. https://wvdnr.gov/wp-content/uploads/2021/05/2015-West-Virginia-State-Wildlife-Action-Plan-Submittal-1.pdf. Accessed 26 Jul 2024
White PS, Tuttle AP (2013) Ecological sustainability as the fourth landmark in the development of conservation ethics. Conserv Biol 27:952–957