Reference Conditions of Central Appalachian Spruce Forests

By Corinne Diggins, Kent Karriker, Melissa Thomas-VanGundy, Jason Teets, and Amy Cimarolli

What Is A Reference Condition?

Ecological restoration attempts to return an ecosystem to a state that existed prior to a major disturbance. Since the majority of ecosystems in the United States were negatively impacted by Euro-American settlement, disturbance typically refers to ecosystems that were altered by human activities (e.g., logging, fire suppression, cattle grazing, river channelization). Desired restored states are within an ecosystem's historical range of variability, which encompasses the fluctuations of conditions and processes within an ecosystem over time (Morgan et al. 1994), taking into account the dynamic complexity inherent in that ecosystem (Egan and Howell 2001). Because an ecosystem cannot be restored to its historical range of variability without knowledge of the conditions that existed prior to disturbance (Egan and Howell 2001), information on pre-disturbed ecosystems is crucial in guiding restoration efforts (Covington and Moore 1994, White and Walker 1997).

Reference conditions are sources of information that help restoration ecologists understand the historical range of variability of an ecosystem prior to disturbance, which guides restoration goals, site selection, and evaluation of restoration treatments (White and Walker 1997, Egan and Howell 2001). Reference conditions are determined by obtaining and interpreting data from references such as historical accounts, historical photographs, early land surveys, undisturbed areas of the ecosystem (e.g., old-growth forest stands), and dendrochronology studies. Reference conditions can be limited spatially and temporally (White and Walker 1997, Egan and Howell 2001), especially in relation to the time since the disturbance and the extent over which the disturbance occurred. Additionally, information on pre-disturbance conditions may be limited for certain ecosystems. Although selecting and applying reference conditions to restoration may be difficult, it is fundamental to the concept of ecological restoration (Fulé et al. 1997, White and Walker 1997).

Reference Conditions for Spruce

Time of Reference

The first step in determining reference conditions for spruce restoration in the Central Appalachians is to select a time of reference. Industrial logging activities began around the turn of the 20th century (Clarkson 1964, Pielke 1981). These logging activities and associated fires are the primary disturbance factor that affected the structure, composition, and extent of spruce forest in eastern West Virginia and western Virginia (Hopkins 1899, Fernow 1905, Newins 1931, Allard and Leonard 1952, Clarkson 1964). Therefore, our time of reference for CASRI spruce restoration efforts is prior to the beginning of industrial logging in the 1880s. As we are considering mature forests dominated by a long-lived and very shade tolerant species, choosing this time implies that environmental conditions and disturbances occurring many centuries before 1880 are incorporated in our reference conditions.

Reference Conditions in the Literature

Sources we used for red spruce-dominated forests of West Virginia and the Appalachians (Table 1) describe many components of spruce-dominated forests in the Central Appalachians. Although some sources are from the northern and southern Appalachians, we chose to include them as the best available published literature.

Composition

Historic accounts indicate that red spruce formed nearly pure stands on the high, rocky ridges and plateaus, where nutrient-poor soils and abundant moisture favored spruce over hardwoods (Hopkins 1899, Brooks 1910, Korstian 1937, Clarkson 1964 and references therein, Core 1966 and references therein). On high elevation slopes where soils are deeper and slightly more fertile, hardwoods or a mixture of hardwoods and spruce predominated (Hopkins 1899, Brooks 1910, Allard and Leonard 1952). However, some accounts suggest that spruce was dominant on the deep, rich, limestone-derived soils that form the floor of Canaan Valley (Strother 1853, Brooks 1910, Allard and Leonard 1952, Clarkson 1964 and references therein, Core 1966 and references therein, McClinton 1996), as well as on the limestone and shale plateaus in the vicinity of the Sinks of Gandy (Hopkins 1899). Hopkins (1899) and Brooks (1910) also indicated that red spruce predominated on the deep, moderately infertile shale-derived soils near the head of the Greenbrier River.

Old growth studies (Oosting and Billings 1951), historic accounts (Shreve et al. 1910, Core 1929), and witness trees (Thomas-Van Gundy et al. 2012) are good sources of information on associated species, with some sources including herbs and forbs. In Virginia, studies of old-growth stands show that hemlock and yellow birch are the species most consistently associated with red spruce (Adams and Stephenson 1991). A study by Adams and Stephenson (1989) displayed that four old-growth sites in West Virginia and Virginia display the variety of species composition found in spruce-dominated forests. At one site 100% of the overstory is comprised of three species (hemlock, red spruce, and yellow birch) while at the other sites, three to seven other species have importance values greater than 0.6 (Adams and Stephenson 1989). For east central West Virginia, red spruce witness trees were associated with beech, birch, and hemlock more frequently than expected by chance and with basswood in one ecological subsection (Thomas-Van Gundy et al. 2012).

There is great variety in these spruce-dominated communities including species composition and landscape position among other factors. Red spruce-dominated upland and lowland community types have been classified for West Virginia (Byers et al. 2007, 2010). While these classifications are based on data from current, largely second-growth, Byers et al. (2007, 2010) classifications support historic accounts of strong spruce dominance on rocky ridges.

Structure

Spruce-dominated old-growth forests of West Virginia and Virginia include many individual dead spruce, making up 36% of all spruce stems and 44% of the total basal area (Adams and Stephenson 1989). Annual mortality has been estimated at about 1% for spruce-fir forests of North Carolina and Tennessee (Busing and Wu 1990) which is similar to the rate found in second-growth red spruce-northern hardwood forests of West Virginia at 1.4% (Rentch et al. 2010). Diameter distributions of old growth stands show large numbers of small diameter trees mixed with scattered large trees that contain most of the basal area (Korstian 1937, Oosting and Billings 1951, Adams and Stephenson 1989, Busing and Wu 1990, Nicholas et al. 1992). Sizes of canopy gaps in spruce-dominated old-growth forests across northeastern North America have been found to have means of 24 to 126m^2 (Seymour et al. 2002). For spruce-fir forests in Tennessee, major natural disturbance regimes include fire, debris avalanches, and wind with return intervals of more than 1,000 years for large gaps (greater than 200m^2 from fires and debris avalanches) and 100 years for small gaps (less than 200$m^2$from wind events; White et al. 1985). Fire and debris avalanches are not likely to play as large a role in the spruce-northern hardwood forests of West Virginia, although the role of fire after exploitative logging of the 1900s is well documented (Clarkson 1993). In northern Appalachian old-growth forests dominated by spruce and fir, no evidence of stand-replacing disturbances was found in the tree ring record (Fraver and White 2005; Fraver et al. 2009).

As spruce forests are dominated by a very shade tolerant and long lived species, we can infer that vertical and horizontal heterogeneity was high before the 1880s. Sub-dominant trees in old-growth stands in West Virginia and Virginia were found to have a mean age of 157 years (Adams and Stephenson 1989). In the southern Appalachians, red spruce required multiple release events to reach the canopy (Wu et al. 1999). Spruce-dominated old-growth in both Tennessee and New Hampshire were determined to have uneven-aged structure (Oosting and Billings 1951).

Soils

Soils harbor tell-tale signs of past red spruce occurrence through the presence of spodic materials. In West Virginia spodic materials are formed by organic acids produced from decomposition/leaching of coniferous and/or ericaceous plant litter strongly reacting within the soil matrix. This soil chemical condition facilitates the transfer of humus and poorly crystalline aluminum and iron from surface to lower horizons. This process is called podzolization (Lundstrom et al. 2000). Spodosols are identified if the horizons made of spodic materials are well developed and meet criteria of a spodic horizon (Soil Survey Staff, 2010). If the soil does not have a spodic horizon, but does contain spodic material, a Spodic Dytrudept is identified. Spodosols or Spodic Dytrudepts serve as definitive markers that conifers once existed on a site.

Spodosols develop within cool, humid climates beneath conifers and thick snow packs (Ciolkosz et al. 1989; Ugolini et al. 1990; Schaetzl and Isard 1996) — conditions that exist at high elevations in West Virginia. Past research verified Spodosol occurrence in West Virginia (Stanley and Ciolkosz 1981) and very small areas of Spodosols are identified in the Randolph, Tucker, Pocahontas, Pendleton, Webster, Grant and Greenbrier County soil surveys. Researchers also studied Spodosols at points southward along the Appalachian Chain (Lietzke and McGuire 1987). Soils with spodic tendencies in the southern Appalachians have been recognized as early as the 1980s, leading to proposals for spodic subgroups for Dystrochrepts and Haplumbrepts (Lietzke and McGuire 1987). Although the existence of spodic horizons does not necessarily equate directly to red spruce as hemlock co-occurs as well throughout much of the former distribution of red spruce, it suggests the cool, humid, boreal climate targeted for restoration.

Extent

In the Central Appalachians, early investigations of spruce forests during the industrial logging period estimated that spruce ranged from half a million to 1.5 million acres (Hopkins 1891, Hopkins 1899, Newins 1931, Core 1950). Spruce occurred down to 2,300 feet in elevation, but it was most abundant at 3,000 feet or more (Hopkins 1899). Pure stands of spruce were common in many areas over 3,200 feet in elevation, typically occurring on well-drained flats and slopes (Core 1950).

Based on the analysis of witness tree locations for the Monongahela National Forest, spruce witness trees in the Western Allegheny Mountains ecological subsection were found at lower elevations than non-spruce witness trees with an average elevation of about 2,000 feet (Thomas-Van Gundy et al. 2012). This may represent scattered individual spruce located on valley landforms and representative of all red spruce ecosystems considered for restoration. However, the witness trees do show differences between ecological subsections and the locations of red spruce, reminding restoration ecologists to be mindful of the range of ecological settings considered possible for restoration actions.

Linking Reference Conditions to Restoration

Once reference conditions are evaluated, they can be used to inform the restoration process (Fulé et al. 1997, White and Walker 1997). For example, after industrial logging in the Central Appalachians, the majority of spruce forests returned as hardwood forests with components of spruce in the understory. Understanding the past extent of spruce forests versus the current extent can highlight focus areas for restoration, especially if management goals are to create corridors between disjunct habitat patches (Figure 1).

Although reference conditions are critical to the restoration process, it is important to understand that reference conditions are guidelines and other factors (e.g., social implications) may influence goals of a restoration project. Additionally, it is important to understand that ecological restoration is not a stagnant process with blanket treatments, but a highly variable process which is inherently experimental (White and Walker 1997). Restoration treatments require on-going management and evaluation over time (Fulé et al. 1997, Kuuluvainen et al. 2002), highlighting the importance of adaptive management (Diggins et al. 2010). Ecosystems are rarely restored with one treatment (Roccaforte et al. 2010), but may require multiple treatments prior to becoming self-sustaining (Covington et al. 1997, Kuuluvainen et al. 2002).

References

Abrams, M.D., and D.M. McCay. 1996. Vegetation-site relationships of witness trees (1780-1856) in the presettlement forests of eastern West Virginia. Canadian Journal of Forest Research 26: 217-224.

Adams, H.S., and S.L. Stephenson. 1989. Old-growth red spruce communities in the mid-Appalachians. Vegetatio 85: 45-56.

Adams, H.S., and S.L. Stephenson. 1991. High elevation coniferous forests in Virginia. Virginia Journal of Science 42(4): 391-399.

Allard, H.A., and E.C. Leonard. 1952. The Canaan and the Stony River Valleys of West Virginia, their former magnificent spruce forests, their vegetation and floristics today. Castanea 17(1): 1-60.

Brooks, A.B. 1910. WV Geological Survey, Volume 5: Forestry and Wood Industries. Acme Publishing Co, Morgantown, WV.

Busing, R.T., and X. Wu. 1990. Site-specific mortality, growth, and structure of a Great Smokey Mountains red spruce population. Canadian Journal of Forest Research 20: 206-210.

Byers, E.A., J.P. Vanderhorst, and B.P. Streets. 2007. Classification and Conservation Assessment of High Elevation Wetland Communities in the Allegheny Mountains of West Virginia. West Virginia Natural Heritage Program, WVDNR. Elkins, WV.

Byers, E.A., J.P. Vanderhorst, and B.P. Streets. 2010. Classification and Conservation Assessment of Upland Red Spruce Communities in West Virginia. West Virginia Natural Heritage Program, WVDNR. Elkins, WV.

Byers, E.A., Byers, K.C. Love, K.R. Haider, E.J. Burks, and J.E. Rowan. 2013. Red Spruce (*Picea rubens)* Cover in West Virginia. Version 1.0 West Virginia Division of Natural Resources, Central Appalachian Spruce Restoration Initiative, Appalachian Forest Heritage Area Americorps, Monongahela National Forest, and U.S. Fish and Wildlife Service. http://wvgis.wvu.edu/data/dataset.php?ID=455

Ciolkosz, E.J., W.J. Waltman, T.W. Simpson, and R.R. Dobos. 1989. Distribution and genesis of soils of the northeastern United States. Geomorphology 2:285-302.

Clarkson, R. B. 1964. Tumult on the Mountains: Lumbering in West Virginia – 1770-1920. McClain Printing Co., Parsons, WV. 410 pp.

Clarkson, R.B. 1993. Destruction of the upland forest by lumbering and fire. In: Eds. Stephenson, S.L. Upland forests of West Virginia. McClain Printing Co., Parsons, WV.

Core, E.L. 1929. Plant ecology of Spruce Mountain, West Virginia. Ecology X(1): 1-13.

Core, E.L. 1950. Notes on the plant geography of West Virginia. Castanea 15(2): 61-79.

Core, E.L. 1966. Vegetation of West Virginia. McClain Printing Co., Parsons, WV.

Covington, W.W., P.Z. Fulé, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Mast, S.S. Sackett, and M.R. Wagner. 1997. Restoring ecosystem health in ponderosa pine forests of the Southwest. Journal of Forestry 95(4): 23-29.

Covington, W.W., and M.M. Moore. 1994. Southwestern ponderosa pine forest structure: Changes since Euro-American settlement. Journal of Forestry 92(1): 39-47.

Diggins, C., P.Z. Fule, J.P. Kaye and W.W. Covington. 2010. Future climate affects management strategies for maintaining forest restoration treatments. International Journal of Wildland Fire 19: 903-913.

Egan, D., and E.A. Howell. 2001. Introduction. Pp. 1-23 *in* Eds. Egan, D. and E.A. Howell. The Historical Ecology Handbook: A Restorationist Guide to Reference Ecosystems. Island Pr. Island Press, Washington D.C.

Egleston, N.H. 1884. Report on forestry, Volume IV. US Department of Agriculture, Government Printing Office: 367-387

Fernow, B.E. 1905. Note on increment of spruce in West Virginia and fire losses. Journal of Forestry 3(4): 346-348.

Fraver, S., and A.S. White. 2005. Disturbance dynamics of old-growth *Picea rubens* forests of northern Maine. Journal of Vegetation Science 16: 597-610.

Fraver, S., A.S. White, and R.S. Seymour. 2009. Natural disturbance in an old-growth landscape of northern Maine, USA. Journal of Ecology 97: 289-298.

Fulé, P.Z., W.W. Covington, and M.M. Moore. 1997. Determining reference conditions for ecosystem management of southwestern ponderosa pine forests. Ecological Applications 7(3): 895-908.

Hopkins, A.D. 1891. Preliminary report: black spruce. West Virginia Agricultural Experiment Station, Bulletin No. 17: 93-102.

Hopkins, A.D. 1899. Report on investigations to determine the cause of unhealthy conditions of the spruce and pine from 1880-1893. West Virginia Agricultural Experiment Station, Bulletin 56: 197-461.

Hough, F.B. 1878. Report upon forestry. USDA Forest Service.

Korstian, C.F. 1937. Perpetuation of spruce on cut-over and burned lands in the higher southern Appalachian Mountains. Ecological Monographs 7(1): 125-167.

Kuuluvainen, T., K. Aapala, P. Ahlroth, M. Kuusinen, T. Lindholm, T. Sallantaus, J. Siitonen, and H. Tukia. 2002. Principles of ecological restoration of boreal forested ecosystems: Finland as an example. Silva Fennica 36(1): 409-422.

Lacey, J.D. 1920. Report of reproduction study West Virginia Pulp and Paper Company lands, Pocahontas, Randolph, and Webster Counties, WVa. James D. Lacey & Co, New York.

Lietzke, D.A. and G.A. McGuire. 1987. Characterization and classification of soils with spodic morphology in the Southern Appalachians. Soil Sci. Soc. Amer. J. 51:165-170.

Lundstrom, U.S., N. van Breeman, and D. Bain. 2000. The podzolization process: A review. Geoderma 94:91-107.

McClinton, A.T. (ed.). 1996. The Fairfax Line: A Historic Landmark, including a replication of Thomas Lewis's Journal of 1746. Shenandoah County Historical Society, Edinburg, VA.

Morgan, P., G.H. Aplet, J.B. Haufler, H.C. Humphries, M.M. Moore, and W.D. Wilson. 1994. Historical range of variability: A useful tool for evaluating ecosystem change. Journal of Sustainable Forestry 2: 87-111.

Newins, H.S. 1931. Forest conditions in West Virginia. Journal of Forestry 29(4): 565-571.

Nicholas, N. S., S. M. Zedaker, C. Eagar, and F. T. Bonner, 1992. Seedling recruitment and stand regeneration in spruce-fir forests of the Great Smoky Mountains. Bull. Torrey Bot. Club 199: 289-299

Oosting, H.J., and W.D. Billings. 1951. A comparison of virgin spruce-fir forest in the northern and southern Appalachian system. Ecology 32(1): 84-103.

Pielke, R.A. 1981. The distribution of spruce in west-central Virginia before lumbering. Castanea 46: 201-216.

Rentch, J.S., T.M. Schuler, G.J. Nowacki, N.R. Beane, and W.M. Ford. 2010. Canopy gap dynamics of second-growth red spruce -northern hardwood stands in West Virginia. Forest Ecology and Management 260: 1921-1929.

Roccaforte, J.P., P.Z. Fulé, and W.W. Covington. 2010. Monitoring landscape-scale ponderosa pine restoration treatment implementation and effectiveness. Restoration Ecology 18(6): 820-833.

Sargent, C.S. 1884. Report on the forests on North America. Department of the Interior, Government Printing Office.

Schaetzl, R.J. and S.A. Isard. 1996. Regional-scale relationships between climate and strength of podsolization in the Great Lakes Region, North America. Catena 28:47-69.

Seymour, R.S., A.S. White, A.S., and P.G. deMaynadier. 2002. Natural disturbance regimes in northeastern North America - evaluating silvicultural systems using natural scales and frequencies. Forest Ecology and Management 155: 357-367.

Shreve, F., M.A. Chrysler, F.H. Blodgett, and F.W. Besley. 1910. The plant life of Maryland. The Johns Hopkins Press, Special Publication, vol. 111.

Soil Survey Staff. 2010. Keys to Soil Taxonomy, 11th ed. USDA-Natural Resources Conservation Service, Washington, DC.

Stanley, S.R. and E.J. Ciolkosz. 1981. Classification and genesis of Spodosols in the Central Appalachians. Soil Sci. Soc. Amer. J. 45:912-917.

Strother, D.H. 1853. The Virginian Canaan. Harpers Magazine 8:16-36. Reprinted in Supplement #20 to the West Virginia Heritage Encyclopedia, 1974.

Thomas-Van Gundy, M., and M. Strager. 2012. European settlement-era vegetation of the Monongahela national forest, West Virginia. USDA

Forest Service, Northern Research Station, General Technical Report NRS-101.
Thomas-Van Gundy, M., M. Strager, and J. Rentch. 2012. Site characteristics of red spruce witness tree locations in the uplands of West Virginia, USA. Journal of the Torrey Botanical Society 139(4): 391-405.
Ugolini, F.C., R. Dahlgren, and K. Vogt. 1990. The genesis of Spodosols and the role of vegetation in the Cascade Range of Washington, U.S.A. P. 370-380 *in* J.M. Kimble and R.D. Yeck (eds.), Proc. 5th Int. Soil Correlation Mtg. Characterization, Classification, and Utilization of Spodosols. USDA-SCS, Lincoln, NE.
White, P.S., M.D. MacKenzie, and R.T. Busing. 1985. Natural disturbance and gap phase dynamics in southern Appalachian spruce-fir forests. Canadian Journal of Forest Research 15 : 223-240.
White, P.S., and J.L. Walker. 1997. Approximating nature's variation: Selecting and using reference information in restoration ecology. Restoration Ecology 5(4): 338-349.
Wu, X., F. McCormick, and R.T. Busing. 1999. Growth pattern of *Picea rubens* prior to canopy recruitment. Plant Ecology 140: 245-253.

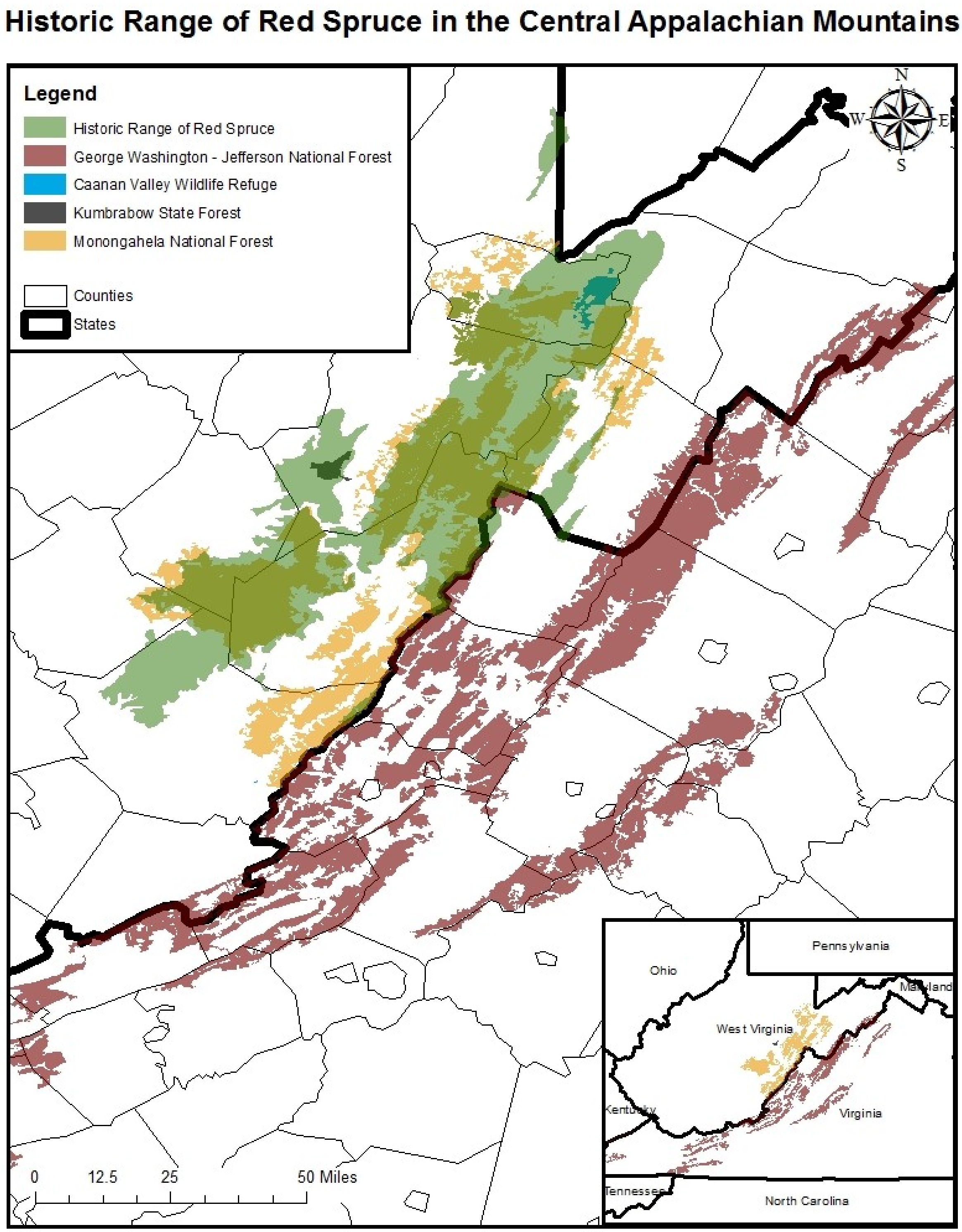

Figure 1. Historical range of red spruce (*Picea abies*) in the Central Appalachians based on Byers et al. 2013.

Table 1 – Literature available for determining historic reference conditions for red spruce-dominated forests.

Type of Reference	Citation	Area of Study	Key Findings
Old-growth study	Adams and Stephenson 1989	WV and VA	• Dead spruce made up 36% of all spruce stems and 44% of the basal area • Size class distributions for red spruce • Low species richness in herb and shrub strata • Sub-dominant trees had mean age of 157 years
	Adams and Stephenson 1991	VA	• Hemlock and yellow birch most consistent associated species • Acidic sandy loam soils with high moisture and organic matter
	Busing and Wu 1990	NC and TN	• Annual mortality about 1% • Small and large trees mortality rate of 0.7% • Intermediate-sized trees mortality rate of <0.5%
	Fraver and White 2005	ME	• No evidence of stand replacing disturbances in tree ring record • Pulses of moderately severe disturbances over a background of small, scattered canopy gaps

			• Calculated gaps sizes • percent of canopy disturbed was on average 10% every decade; rarely exceeded 35%; range of rates may be more important than means • Peaks in disturbance correspond to spruce budworm outbreaks
	Fraver et al. 2009	ME	• No evidence of stand replacing disturbances • 9.6% canopy loss per decade • Patches in stages of structural development not in stages of compositional succession; shade tolerant dominated system
	Oosting and Billings 1951	TN and NH	• Species lists, including herbs, mosses, and liverworts • Stems/ac and basal area/ac by stand for trees and shrubs • Tree size did not always correspond to tree age • Uneven-aged structure • Northern and southern forests quite similar
	Seymour et al.	Northeastern	• Canopy gaps -

	2002	North America	mean size 24-126m^2, return interval 50-200 years • Stand replacing wind – 14-93 ha, 855-14300 years • Stand replacing fire – 2-200ha, 806-9000 years
	White et al. 1985	TN	• Fire, debris avalanches, and wind included in the natural disturbance regimes with return intervals of more than 1,000 years for large gaps (>200m^2) and 100 years for small gaps (<200m^2) • Area affected 0.1% by large gaps, 5-20% by small gaps • Relative and absolute densities of stands
	Wu et al. 1999	TN	• Multiple release events may be needed for red spruce to reach canopy • Release events before canopy recruitment were from small and frequent gaps
Early land survey	Abrams and McCay 1996	WV	• Spruce in coves and valley floor in Ridge and Valley province • Spruce on mountain-top, SE slopes, coves, and valley floors in

			Allegheny Mountains
	Thomas-Van Gundy and Strager 2012	WV	• Maps showing witness tree locations, clusters, and interpolated surface with probability of occurrence
	Thomas-Van Gundy et al. 2012	WV	• Red spruce in the Western Allegheny Mountains subsection at significantly lower elevation than other species, elsewhere spruce at higher elevation • Indicator specs found spruce associated with toe slopes, benches, and valleys, NE aspects, and Mandy soils • Associated with beech, birch, and hemlock across study area and basswood in Eastern Allegheny Mountain and Valley subsection
Historic account	Allard and Leonard 1952	WV	• Variety of landscape positions – ridges, valley floor, mountain slopes • Associated tree, shrub, and forbs/herbs • Descriptions of the aftermath of fire and logging
	Brooks 1910	WV	• Brief descriptions of

			pre-logging forest species composition for most of WV • 10% of the timber in Tucker County was red spruce on the high mountains in the southern end eastward from Backbone Mountain • Spruce dominant on high ridges, Canaan Valley, headwaters of Greenbrier River
	Core 1929	WV	• Species lists • descriptions of burned areas
	Core 1966	WV	• Re-telling of early accounts of forest composition in WV • Spruce dominant on high ridges and in Canaan Valley
	Clarkson 1964	WV	• Re-telling of early accounts of forest composition in WV • Spruce dominant on high ridges and in Canaan Valley
	Egleston 1884	WV	• Description of spruce forests in Cheat Mountain area – above 3,000 feet • Also known as yew-pine • Inaccessible in 1884 • Locations of saw mills in 1880 • Percent woodland by county in 1870

			and 1880
	Hopkins 1891	WV	• General extent of spruce forest by county – exceeded 500,000 acres • Patchy overstory death between 1880 and 1882 • Larger trees more affected than small • Results of survey sent to lumber companies about the spruce death • Black cherry replacing spruce in Tucker County • Spruce on rocky areas likely died from drought • Beetles had role as well
	Hopkins 1899	WV	• Detailed account of beetle kill of spruce and pine in WV during 1880s-1890s • Described original extent and composition of spruce forest in WV • Spruce predominant on high ridges, Sinks of Gandy, head of Greenbrier River
	Hough 1878	WV	• Evergreen timber in the mountains at 3,000 to 3,200 feet in south and at 2,500 feet in the north • “Hemlock abounds most in the Cheat River and

			Greenbrier Mountains…” should this be spruce?
	Korstian 1937	WV	• Nearly pure stands of spruce on high, rocky ridges • Stems per acre of old-growth stand • Results of early release cutting
	Lacey 1910	WV	• Locations and timing of harvests of last virgin stands in the Cheat and Elk watersheds • Pure spruce on ridges, spruce and hardwoods on slopes (Cheat) • Logging of spruce on Cheat watershed began in 1902
	McClinton 1996	WV	• Modern compilation of journal of Thomas Lewis’ survey of the Fairfax line (1746) • Spruce predominant along “River Styx” (likely the headwaters of the Blackwater River in Canaan Valley)
	Sargent 1884	WV	• Extent of spruce forests by county and sometimes nearby towns • Spruce noted on the Cheat river and tributaries • Eastern limit of spruce –headwaters

			of Elk and Gauley rivers - meets the western limit of white pine belt in Pocahontas County
	Shreve 1910	Western MD	• Species lists • Occurrence of spruce on different landforms
	Strother 1853	WV	• Account of an early expedition to Canaan Valley • Forest dominated by “fir” and “laurel” (likely spruce, hemlock, and great rhododendron)