13700

Appalachian (Hemlock-)Northern Hardwood Forest

BpS Model/Description Version: Aug. 2020

|  |  |  |  |
| --- | --- | --- | --- |
| **Modelers** |  | **Reviewers** |  |
| Kim J Brown | treebiology@gmail.com | None | None |
| KellyAnn F Gorman | kellyann\_gorman@nps.gov | None | None |
| None | None | None | None |

**Reviewed by:** Samantha Chapman, Adam Langley, and Randy Swaty

Vegetation Type

Forest and Woodland

Map Zones

60, 63, 64, 65, 66

Geographic Range

Generally, ranges from Pennsylvania west to Lake Erie and south to northern Georgia, eastern Kentucky, southeastern Ohio, western North Carolina, northwestern South Carolina, eastern Tennessee, southwestern West Virginia, western Virginia, the Appalachian Mountains, and the Cumberland Plateau. May also be on the upper Piedmont.

Canada hemlock (*Tsuga canadensis*) extends from Maine and Nova Scotia south to northern Alabama and Georgia. Includes physiographic provinces 212b, 212c, 212d, 212e, 212f, 212g, 221a, 221b, 221d (may also include others).

Biophysical Site Description

This mixed forest occurs predominantly on mesic sites over a broad range of topographic conditions with elevations generally ranging from 1,000-3,000ft. Sites remain moist in all but the most severe drought conditions. The Biophysical Setting (BpS) shifts from occupying a broad elevation range in the northern extent of the map zone (MZ) (Pennsylvania) to a narrower range (higher elevation) in the southern extent of the MZ (West Virginia).

In the northern portion of its range, it occurs primarily at higher elevations and on slope positions that favor cool, moist conditions. Soils are usually acidic and can contain a variety of parent material and drainage conditions.

At lower elevations and in the southern portion of its range, it occurs more frequently in sheltered coves and valleys. Sites are acid, generally on moist but moderately well-drained to well-drained loamy or silty soils, either colluvial or alluvial. Soils are often rocky and usually deep (>40in), even if only in pockets between boulders. In riparian areas, it is usually along high gradient (1-2%) streams. Also found on lower slopes with west and south aspect, lower to mid slope on east and north aspects, and in narrow cliff bound valleys; it may occur to the base of cliffs on all slopes.

Vegetation Description

In the northern part of the range, dominant overstory species include eastern hemlock (*Tsuga canadensis*), American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and yellow birch (*Betula allegheniensis*). While this community as a whole occurs across a wide range of topographic conditions, the species mix can vary considerably. Hemlock will dominate the overstory on cool/moist sites at higher elevations and in shaded coves, valley bottoms, and riparian areas. Moist bottomlands and footslopes may also contain a larger component of yellow birch, white ash (*Fraxinus americana*), and sycamore (*Platanus occidentalis*) (Whitney 1990). Locally, on slopes, sugar maple becomes more abundant, resulting in a beech-hemlock-sugar maple complex (Braun 2001). Other common associates include red maple (*Acer rubrum*), black cherry (*Prunus serotina*), black birch (*Betula nigra*), basswood (*Tilia americana*), and cucumber magnolia (*Magnolia acuminata*). The understory and mid-story are usually well developed and include hobblebush (*Viburnum alnifolium*), mapleleaf viburnum (*Viburnum acerifolium*), witch hazel (*Hamamelis virginiana*), serviceberry (*Amelanchier alnifolia*), pin cherry (*Prunus pensylvanica*), large-leaved holly (*Ilex monticola*), and alternative-leaved dogwood (*Cornus alternifolia*). Common herbaceous species include wild lily of the valley (*Maianthemum canadense*), sensitive fern (*Onoclea sensibilis*), shining clubmoss (*Lycopodium lucidulum*), *Dryopteris spinulosa* (*Dryopteris spinulosa*), mountain woodsorrel (*Oxalis montana*), and partridgeberry (*Mitchella repens*) (Lutz 1930; Braun 2001).

In the southern part of the range, dominant vegetation is generally in two to three layers. The canopy in well-developed late seral conditions is composed of eastern hemlock (*Tsuga canadensis*) (most common) and/or white pine (*Pinus strobus*) mixed with various hardwoods, including tulip poplar (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), black and white oaks (*Quercus velutina*, *Q. alba*), black birch (*Betula lenta*), and bigleaf and umbrella magnolias (*Magnolia macrophylla*, *M. tripetala*). In the southern Appalachians, Fraser magnolia (*M. fraseri*) and silverbell (*Halesia carolina*) may also be found. There may be gaps with a younger cohort of the same set of species. A dense, low- to high-shrub layer of great laurel (*Rhododendron maxima*) and sometimes mountain laurel (*Kalmia latifolia*) is often present. Yellowroot (*Xanthorhiza simplissima*) may occur immediately adjacent to streams in sandy/silty alluvial deposits in gaps. Few if any herbs are found, and bryophyte and hepatophyte cover is generally restricted to downed wood, tree/shrub boles, and rocks/boulders.

BpS Dominant and Indicator Species

|  |  |  |
| --- | --- | --- |
| **Symbol** | **Scientific Name** | **Common Name** |
| FAGR | *Fagus grandifolia* | American beech |
| TSCA | *Tsuga canadensis* | Eastern hemlock |
| ACSA3 | *Acer saccharum* | Sugar maple |
| BEAL2 | *Betula alleghaniensis* | Yellow birch |
| TIAM | *Tilia americana* | American basswood |
| LITU | *Liriodendron tulipifera* | Tuliptree |
| PIST | *Pinus strobus* | Eastern white pine |
| QUVE | *Quercus velutina* | Black oak |

Species names are from the NRCS PLANTS database. Check species codes at http://plants.usda.gov.

Disturbance Description

Non-Fire Disturbance: This system is dominated by long-lived, mesic species that form multilayered, uneven-aged forests over time. Canopy dynamics are dominated by single and multiple disturbances, encouraging gap phase regeneration (Abrams and Orwig 1996). Larger disturbances include windthrow, insect attack, and ice storms. Although stand-replacing wind events are rare, small to medium blowdown events are more common and occur at greater frequency on the plateau and exposed side slopes (Ruffner and Abrams 2003). Localized insect and disease outbreaks can create small to medium canopy gaps.

Running the VDDT model resulted in 0.9% disturbance (fire and/or wind, weather, stress) annually, consistent with disturbance rates documented by Runkle (1981, 1985) and others. Wind, weather, stress alone resulted in 0.7% disturbance annually.

Fire Regime Description: Historically, this system was probably only subject to occasional fires. Fires that did occur may have been catastrophic and may have led to even-aged stands of pine and hemlock (NatureServe 2007).

Due to the predominance of cool, moist site conditions, surface and replacement fires are extremely rare, occurring at 700-1,000yr intervals. Most protected sites are essentially fire-free. The principal cause of fuel formation leading to fire in northern hardwood ecosystems is broad-scale, storm-driven windthrow of catastrophic proportions (Hough 1963, Runkle 1982).

Fire Frequency

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Severity** | **Avg FI** | **Percent of All Fires** | **Min FI** | **Max FI** |
| Replacement | 1005 | 53 |  |  |
| Moderate (Mixed) | 1118 | 47 |  |  |
| Low (Surface) |  |  |  |  |
| All Fires | 529 | 100 |  |  |

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is the central tendency modeled. Percent of all fires is the percent of all fires modeled in that severity class. Minimum and Maximum FIs show the relative range of fire intervals as estimated by model contributors, if known.

Scale Description

NatureServe (2007) notes that this BpS is a matrix in the northern portion of its range to large patch on the southern end of its range in Virginia and West Virginia, and some examples may be as large as 1,000ac but smaller in the southern part of the range.

Both small- and large-scale disturbances characterize the natural disturbance regime of this region, with wind, insects/diseases, and ice storms as primary disturbance agents. These forests are characterized by small-scale disturbance, with a high degree of vertical structure and fine-grained patch size (Spies 2004). This disturbance regime strongly favors tolerant species but allows opportunists to persist in low densities (Runkle 1982). On high plateaus and exposed slopes, small-scale wind disturbances are a common agent driving gap dynamics (Ruffner and Abrams 2003). However, medium-scale intensity disturbances also characterize the region (Runkle 1982; Ruffner, unpublished). A significant glazing or ice storm event can be expected every 50yrs or so (Hough, 1963). Depending on the severity of ice loading, damage may range from minimal to severe crown damage.

Gap sizes range from 28 square meters to 2,000 square meters, with a mean of 200 square meters. Canopy turnover rates of 0.5-2% per year with a return interval of 50-200yrs characterize old-growth beech and hemlock stands (Runkle 1981, 1985). Repeat disturbances affecting the same location may be common. More recent estimates of the return interval based on actual tree ring analysis suggest that 10-20% of the canopy may be disturbed every decade depending on the topographic position of the stand (Ruffner, unpublished).

Along streams in the southern part of the range, stands range from 2-3ac to >200ac in some areas, much smaller than typical stand sizes in the northern tier.

**Adjacency or Identification Concerns**

Using the International Ecological Classification Standard, this system corresponds to the Appalachian (Hemlock)-Northern Hardwood Forest (CES202.593) (NatureServe 2007). However, the concept of this system was revised in April 2007 to remove areas south and west of Virginia and West Virginia from its range. The Region 8 National Forests and other Federal lands, as well as ecoregions and MZs related to this area, were also removed (NatureServe 2007).

Northward this system is replaced by Laurentian-Acadian Pine-Hemlock-Hardwood Forest (CES201.563 -- BpS 1366) and Laurentian-Acadian Northern Hardwoods Forest (CES201.564 -- BpS 1302), but the limits of both are not yet clear in western New York (Allegheny Plateau) and central New England. USFS ecological province lines provide an apparently appropriate delimiter, with areas in Provinces 212 and M212 (as well as the Great Lakes part of 221 in New York and Ohio) falling into the Laurentian-Acadian systems and areas in Provinces 221 and M221 falling into this Appalachian system (NatureServe 2007).

As written, this model includes the moist, acid, lower-elevation landscape position variant of NatureServe's 202.373 (Southern and Central Appalachian Cove Forest). R8HEWP – Hemlock -- White Pine -- Hardwood differs from R7NHHE -- Northern Hardwood Hemlock in fire and disturbance regimes and in structure but shares key composition elements and successional pathways.

The four "Northern Hardwood" models in the Rapid Assessment (RA) (R6NHMB, R7NHHE, R7NHNE, and R7NHSP) occur across both the Northeast and Great Lakes model zones and have several similarities, including: high moisture/nutrient gradients; historical inclusion of more conifer; frequent dominance by sugar maple; and windthrow as the main disturbance agent with fires occurring every ~1,000-2,000yrs. There are also several differences, including: the limited extent of beech west of eastern Wisconsin and the central Upper Peninsula of Michigan; and the variation in the amount of hemlock.

Non-Fire Disturbances

Wind/Weather/Stress

Adjacency or Identification Concerns

Using the International Ecological Classification Standard, this system corresponds to the Appalachian (Hemlock)-Northern Hardwood Forest (CES202.593) (NatureServe 2007). However, the concept of this system was revised in April 2007 to remove areas south and west of Virginia and West Virginia from its range. The Region 8 National Forests and other Federal lands, as well as ecoregions and MZs related to this area, were also removed (NatureServe 2007).

Northward this system is replaced by Laurentian-Acadian Pine-Hemlock-Hardwood Forest (CES201.563 -- BpS 1366) and Laurentian-Acadian Northern Hardwoods Forest (CES201.564 -- BpS 1302), but the limits of both are not yet clear in western New York (Allegheny Plateau) and central New England. USFS ecological province lines provide an apparently appropriate delimiter, with areas in Provinces 212 and M212 (as well as the Great Lakes part of 221 in New York and Ohio) falling into the Laurentian-Acadian systems and areas in Provinces 221 and M221 falling into this Appalachian system (NatureServe 2007).

As written, this model includes the moist, acid, lower-elevation landscape position variant of NatureServe's 202.373 (Southern and Central Appalachian Cove Forest). R8HEWP-- Hemlock -- White Pine -- Hardwood differs from R7NHHE -- Northern Hardwood Hemlock in fire and disturbance regimes and in structure but shares key composition elements and successional pathways. In the most protected sites, R8HEWP tends toward R7SHEM in older age classes.

Issues or Problems

This community has been significantly altered through exotic insect and diseases, including the beech scale disease complex, which has been causing widespread mortality of American beech for the last 20yrs, and more recently the hemlock woolly adelgid, which kills hemlock in all age and size classes. It is also threatened by global warming, as hemlock is typically found in cooler microclimates. These factors will reduce the range and extent of the vegetation type.

This system is currently being devastated in large parts of its range by the hemlock woolly adelgid (*Adelges tsugae*). This sucking insect is continuing to cause close to 100% mortality as it spreads from the north into the southern United States. The insect will most likely cause canopy hemlocks to be replaced by other canopy trees (NatureServe 2007).

Native Uncharacteristic Conditions

Past logging in many areas has altered this system by creating a predominantly even-aged structure, which contains a much higher proportion of shade-intolerant species. In many areas, this change in species composition is further aggravated by decades of overbrowsing by deer (Runkle 1982; Abrams and Orwig 1996), which has significantly reduced the hemlock component and reduced species and structural diversity in many areas.

Sugar maple decline is another current forest health concern that is attributed to a combination of factors including insect defoliations, drought, and site factors related to soil nutrient status (impacted by acid deposition) (Horsley et al., 2002). Second-growth stands are characterized by an underrepresentation of significant habitat elements such as large diameter trees, canopy gaps, gap saplings, “tip-up” mounds, coarse woody debris, and a limited range of seral stages (Litvaitis, 2003; Lorimer and Frelich 1994).

Other forest health concerns in the region include changing soil nutrient status due to acid deposition and concerns about potential increases in ozone from industrial byproducts.

Comments

Succession Classes

**Mapping Rules**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Upper Layer Lifeform** | **Height (m)** | **Canopy Cover (%)** | | | | | | | | | |
| **0-10** | **11-20** | **21-30** | **31-40** | **41 - 50** | **51-60** | **61-70** | **71-80** | **81-90** | **91-100** |
| Herb | 0-0.5 | UN | UN | UN | UN | UN | UN | UN | UN | UN | UN |
| Herb | 0.5-1.0 | UN | UN | UN | UN | UN | UN | UN | UN | UN | UN |
| Herb | >1.0 | UN | UN | UN | UN | UN | UN | UN | UN | UN | UN |
| Shrub | 0-0.5 | UN | UN | UN | UN | UN | UN | UN | UN | UN | UN |
| Shrub | 0.5-1.0 | UN | UN | UN | UN | UN | UN | UN | UN | UN | UN |
| Shrub | 1.0-3.0 | UN | UN | UN | UN | UN | UN | UN | UN | UN | UN |
| Shrub | >3.0 | UN | UN | UN | UN | UN | UN | UN | UN | UN | UN |
| Tree | 0-5 | UN | UN | UN | UN | UN | UN | UN | A | A | A |
| Tree | 5-10 | UN | UN | UN | UN | C | C | C | A | A | A |
| Tree | 10-25 | UN | UN | UN | UN | C | C | C | B | B | B |
| Tree | 25-50 | UN | UN | UN | UN | C | C | C | D | D | D |
| Tree | >50 | UN | UN | UN | UN | UN | UN | UN | UN | UN | UN |

Succession class letters A-E are described in the Succession Class Description section. Some classes use a leafform distinction where a qualifier is added to the class letter: Brdl (broadleaf), Con (conifer), or Mix (mixed conifer and broadleaf). UN refers to uncharacteristic native or a combination of height and cover that would not be expected under the reference condition. NP refers to not possible or a combination of height and cover which is not physiologically possible for the species in the BpS.

**Description**

Class A 9 Early Development 1 - All Structures

Indicator Species

|  |  |  |  |
| --- | --- | --- | --- |
| **Symbol** | **Scientific Name** | **Common Name** | **Canopy Position** |
| ACRU | Acer rubrum | Red maple | Mid-Upper |
| LITU | Liriodendron tulipifera | Tuliptree | Upper |
| FAGR | Fagus grandifolia | American beech | Mid-Upper |
| TSCA | Tsuga canadensis | Eastern hemlock | Low-Mid |

Description

Early age classes include forests <50yrs of age. Initially young stands have an even-aged structure and may include birches, tulip poplar, beech, basswood, white ash, hemlock, red maple, and black cherry. In the southern parts of the range, white pine, magnolia, and a few oaks may also be present. As the stand matures, intermediate and intolerant species move into the canopy with beech and hemlock existing in the understory and midstory. Tree size ranges from seedling through poles. Closed canopy conditions exist throughout most of this class, and with the exception of the early stand initiation phase, there is little development of herbaceous or shrubby vegetation.

*Maximum Tree Size Class*  
Pole 5-9" DBH

Class B 14 Mid Development 1 - Closed

Indicator Species

|  |  |  |  |
| --- | --- | --- | --- |
| **Symbol** | **Scientific Name** | **Common Name** | **Canopy Position** |
| TSCA | Tsuga canadensis | Eastern hemlock | All |
| FAGR | Fagus grandifolia | American beech | All |
| ACSA3 | Acer saccharum | Sugar maple | All |
| ACRU | Acer rubrum | Red maple | Lower |

Description

Closed canopy conditions exist throughout the life of this class. Beech and hemlock move into the middle to upper portions of the canopy, with white pine in the southern reaches, and the overstory will include a mixture of intermediate and intolerant species such as yellow birch, tulip poplar, red and sugar maple, basswood, ash, magnolias, black cherry, and a few oaks (black, white). Both even- and uneven-aged stand structure conditions may exist, and forests in this class will start to develop a well-established shrub and herbaceous layer; mountain and/or great laurel can be present in dense patches.

*Maximum Tree Size Class*  
Large 21-33" DBH

Class C 9 Mid Development 1 - Open

Indicator Species

|  |  |  |  |
| --- | --- | --- | --- |
| **Symbol** | **Scientific Name** | **Common Name** | **Canopy Position** |
| LITU | Liriodendron tulipifera | Tuliptree | All |
| BEAL2 | Betula alleghaniensis | Yellow birch | All |
| FAGR | Fagus grandifolia | American beech | All |
| TSCA | Tsuga canadensis | Eastern hemlock | Upper |

Description

This class is characterized by more open canopy conditions resulting from partial blowdown, ice glaze events, localized insect and disease outbreaks, or mixed-severity fire. Greater than 20% overstory mortality occurs during these events, which creates open canopy conditions and stimulates development of the understory and midstory. Associate intermediate and intolerant species such as red maple, black birch, ash, red and/or sugar maple, black cherry, basswood, and magnolias will become established in greater abundance. Great and/or mountain laurel may be present in dense patches. Canopy gaps close laterally, and this class succeeds to D within 2-3 decades. Fuel model 10 may occur where windthrow has created large quantities of slash.

*Maximum Tree Size Class*  
Large 21-33" DBH

Class D 68 Late Development 1 - Closed

Indicator Species

|  |  |  |  |
| --- | --- | --- | --- |
| **Symbol** | **Scientific Name** | **Common Name** | **Canopy Position** |
| TSCA | Tsuga canadensis | Eastern hemlock | All |
| FAGR | Fagus grandifolia | American beech | All |
| ACSA3 | Acer saccharum | Sugar maple | All |
| LITU | Liriodendron tulipifera | Tuliptree | Upper |

Description

Class D is characterized by an uneven-aged, closed-canopy structure with beech, hemlock, and sugar maple occurring in all size classes. The overstory is characterized by large-diameter beech, hemlock, sugar maple, and tulip poplar, with white pine in the southern parts. In hemlock-dominated stands, the shrub layer consists almost exclusively of shade-tolerant shrub species, with a less well-developed herbaceous layer; in hardwood-hemlock mixes, a well-developed shrub and rich herbaceous layer is often present. Great and/or mountain laurel may still be present in mixed stands. Oldest trees are 200-350yrs old and sometimes >400yrs old.

*Maximum Tree Size Class*  
Very Large >33" DBH

Model Parameters

Deterministic Transitions

|  |  |  |  |
| --- | --- | --- | --- |
| **From Class** | **Begins at (yr)** | **Succeeds to** | **After (years)** |
| Early1:ALL | 0 | Mid1:CLS | 49 |
| Mid1:OPN | 50 | Mid1:OPN | 199 |
| Mid1:CLS | 50 | Late1:CLS | 199 |
| Late1:CLS | 200 | Late1:CLS | 999 |

Probabilistic Transitions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Disturbance Type** | **Disturbance occurs In** | **Moves vegetation to** | **Disturbance Probability** | **Return Interval (yrs)** | **Reset Age to New Class Start Age After Disturbance?** | **Years Since Last Disturbance** |
| Wind or Weather or Stress | Early1:ALL | Early1:ALL | 0.001 | 1000 | No | 0 |
| Replacement Fire | Early1:ALL | Early1:ALL | 0.001 | 1000 | Yes | 0 |
| Alternative Succession | Mid1:OPN | Late1:CLS | 1 | 1 | Yes | 100 |
| Mixed Fire | Mid1:OPN | Mid1:OPN | 0.001 | 1000 | No | 0 |
| Wind or Weather or Stress | Mid1:OPN | Early1:ALL | 0.001 | 1000 | Yes | 0 |
| Replacement Fire | Mid1:OPN | Early1:ALL | 0.001 | 1000 | Yes | 0 |
| Wind or Weather or Stress | Mid1:OPN | Mid1:OPN | 0.0071 | 141 | No | 0 |
| Mixed Fire | Mid1:CLS | Mid1:OPN | 0.001 | 1000 | Yes | 0 |
| Wind or Weather or Stress | Mid1:CLS | Early1:ALL | 0.001 | 1000 | Yes | 0 |
| Replacement Fire | Mid1:CLS | Early1:ALL | 0.001 | 1000 | Yes | 0 |
| Wind or Weather or Stress | Mid1:CLS | Mid1:OPN | 0.0071 | 141 | Yes | 0 |
| Mixed Fire | Late1:CLS | Mid1:OPN | 0.001 | 1000 | Yes | 0 |
| Wind or Weather or Stress | Late1:CLS | Early1:ALL | 0.001 | 1000 | Yes | 0 |
| Replacement Fire | Late1:CLS | Early1:ALL | 0.001 | 1000 | Yes | 0 |
| Wind or Weather or Stress | Late1:CLS | Mid1:OPN | 0.0071 | 141 | Yes | 0 |

References

Abrams, M.D. and D.A. Orwig. 1996. A 300-year history of disturbance and canopy recruitment for co-occurring white pine and hemlock on the Allegheny Plateau, USA. Journal of Ecology. 84:353-363.

Braun, E.L. 2001. Deciduous forests of Eastern North America. 2nd ed. The Blackburn Press. 596 pp.

Delcourt, H.R. and Delcourt, P.A. 1988. Quaternary landscape ecology: relevant scales in space and time. Landscape Ecol. 2: 23-44.

Horsley, S.B, R.P. Long, S.W. Bailey et al. 2002. Health of eastern North American sugar maple forests and factors affecting decline. North J Applied For 19:34–44.

Hough, A. F. 1936. A climax forest community on East Tionesta creek in Northwest Pennsylvania. Ecology 17(1):9-28.

Hough, A. F. 1963. What a glaze storm brings. PA Forestry 53:4-5.

Ison, Cecil R. 2000. Fire on the edge: prehistoric fire along the escarpement zone of the Cumberland Plateau. In: Yaussy, Daniel A., compiler. Proceedings: workshop on fire, people, and the central hardwoods landscape; 2000 March 12-14; Richmond, KY. Gen. Tech. Rep. NE-274. Newtown Square, PA: USDA Forest Service, Northeastern Research Station. 36-45.

Litvaitis, J.A. 2003. Are pre-Columbian conditions relevant baselines for managed forests in the northeastern United States? Forest Ecology and Management 185:113-126.

Lorimer, C.G. and L.E. Frelich. 1994. Natural disturbance regimes in old-growth northern hardwoods. Journal of Forestry 92:33-38.

Lutz, H.J. 1930. The vegetation of hearts content, a virgin forest in northwestern Pennsylvania. Ecology. Vol. XI (1). 29 pp.

Martin, W.H. 1975. The Lilley Cornett Woods: A stable mixed mesophytic forest in Kentucky. Botanical Gazette 136:171-183.

NatureServe. 2007. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Databases. Arlington, VA, U.S.A. Data current as of 08 June 2007.

Ruffner, C.M. and M.D. Abrams. 2003. Historical ecology of Allegheny plateau forests. Submitted to the Allegheny National Forest as a component of the revised forest plan. Unpublished. 19pp.

Runkle, J.R. 1981. Gap regeneration in some old-growth forests of the eastern United States. Ecology 62:1041-1051.

Runkle, J.R. 1982. Patterns of disturbance in some old-growth mesic forests of Eastern North America. Ecology 63(5):1533-1546.

Runkle, J.R. 1985. Disturbance regimes in temperate forests. In: The ecology of natural disturbance and patch dynamics. Edited by S.T.A. Pickett and P.S. White. Academic Press, NY. 17-33.

Spies, T.A. 2004. Ecological concepts and diversity of old-growth forests. Journal of Forestry 102:14-20.

Thompson, R. L., R.L. Jones, J. Abbott, J. Richard and W.N. Denton. 2000. Botanical survey of Rock Creek Research Natural Area, Kentucky. Gen. Tech. Rep. NE-272. Newtown Square, PA: USDA Forest Service, Northeastern Research Station. 23 pp.

Whitney, G.G. 1990. The history and status of the hemlock-hardwood forests of the Allegheny plateau. Journal of Ecology 78:443-458.