CHARACTERIZATION OF THE VEGETATION AND SOIL OF THE FOREST COMMUNITIES AT CAMP BROOKSIDE IN SUMMERS COUNTY, WEST VIRGINIA

by

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ABSTRACT

Camp Brookside, a seasonal island, is located on the floodplain of the New River in Summers County, West Virginia. This island hosts several rare plant species and a rare plant community known as a riverside flat rock plant community (FRPC). The FRPC is characterized by flat resistant sandstone shelves above water that are generally associated with rapids. Flooding has historically maintained the FRPC by scouring any soil off of the bedrock and leaving sand deposits in cracks or depressions. However, since the Bluestone Dam was built in 1950, organic material accumulation and soil development has gone unabated. Measurements were taken of the overstory, lower canopy, regeneration layers, and soils found at Camp Brookside. Our overstory data indicated that there are five distinct plant communities on the island. The FRPC has an overstory of eastern redcedar (*Juniperus virginiana*), Virginia pine (*Pinus virginiana*), and white ash (*Fraxinus americana*). The FRPC has an average soil depth of 1.8 cm, a loamy sand soil texture, and a soil pH of 3.9. A xeric pine community dominated by Virginia pine and eastern redcedar was found along the riverside portion of the island. Historically, this community was part of the FRPC. The xeric pine community has an average soil depth of 17.6 cm, a loamy sand soil texture, and a soil pH of 4.6. Our results indicate that soil and organic material is accumulating in the FRPC, and that some type of disturbance will be needed to maintain this community.

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INTRODUCTION

The National Park Service (NPS), New River Gorge National River (NRGNR), has expressed concern about natural plant succession in the riverside flat rock plant community (FRPC) at Camp Brookside, Summers County, West Virginia. Camp Brookside has the largest known concentration of rare plant species within the NRGNR (Rouse and McDonald, 1986). Riparian hardwoods, exotic trees, shrubs, and vines are slowly colonizing the lower canopy of this community as natural weathering, organic matter deposition, and plant succession occur. The FRPC was created and maintained by periodic flooding of the New River (Trianosky, 1995). However, since the Bluestone Dam was constructed in 1949, flooding waters have been less frequent and less catastrophic, allowing typical riparian forest tree species to become established in the FRPC.

Natural disturbances, including debris avalanches, droughts, fires, floods, and ice storms, provide unique habitats that certain plant species and communities depend upon. On Camp Brookside, flooding has historically maintained the FRPC by scouring the soil off of the sandstone bedrock while depositing sand in cracks or small depressions. In addition, rivers are a seed source that can lead to high concentrations of rare species on islands or along the river's edge. Other plant communities such as glades, barrens, rock outcrops, and the Everglades are also maintained by disturbances. Glades and barrens have historically been maintained by cultivation, drought, erosion, fire, floods, quarrying, and the manual removal of woody vegetation. Glade and barren communities have been extensively studied in many states near and east of the Mississippi River due to their harsh growing conditions, commonly high levels of diversity, and unique flora (Kucera

and Martin 1957; Bartgis 1993; Quarterman et al. 1993; Baskin et al. 1994; Heikens and Robertson 1995). Rock outcrops are typically maintained by drought, erosion, and fire. The granite outcrop communities and high elevation rock outcrop communities have been studied because of their extremely harsh growing conditions and the presence of rare species (Burbanck and Platt 1964; Phillips 1981; Burbanck and Phillips 1983; Wiser and White 1999). The marshlands of the Everglades are maintained by both frequent fires and fluctuating water levels. The Everglades have been extensively studied due to its value as an abundant water supply for parts of Florida, its importance as wildlife habitat, and the fact that it is a unique ecosystem (Tanner et al. 1982; Kushlan 1990; Lodge 1994).

OBJECTIVE

The objective of this study was to assess the current status of the plant communities found at Camp Brookside. This was accomplished by characterizing the overstory vegetation, lower canopy vegetation, regeneration, and soils of the plant communities found at Camp Brookside. This study will provide the baseline data needed for future comparisons of organic matter accumulation, soil development, and plant community composition and structural changes within the FRPC.

LITERATURE REVIEW

There have been many discussions and disagreements over the terminology used to describe disturbance-maintained plant communities. The terms “glade” and “barrens” are at the forefront of these discussions. Terminology for these communities has varied over time and by location. Quarterman (1950) stated that glades are open spaces with exposed rock at or near the surface. These areas included exposed rock surfaces with grassy expanses surrounded by cedar woods. Menges and Wade (1986) described glades as being underlain with a very shallow soil generally incapable of supporting vegetation except in cracks in the bedrock, while barrens are described as areas with soil deep enough to allow establishment of cedar and other woody vegetation. Deselm (1986) stated that glades typically occur on limestone outcrops and are sparsely covered by annual and perennial vegetation, while barrens are naturally maintained herbaceous plant communities dominated by mid-height and tall grasses of the tall grass prairies. Quarterman et al. (1993) distinguished glades as containing less than 50% perennial grass cover, while barrens have greater than 50% perennial grass cover. Baskin et al. (1994) discusses a new system for looking at these communities by using information from the site, including geology, soil, vegetation, and terrain characteristics. Further discussions on the characteristics of these types of disturbance-maintained communities will help us communicate more effectively and gain a better understanding of how they differ.

Glades

Glades are characterized by early successional plant communities growing on shallow, rocky soil overlying resistant beds of limestone or sandstone. Low moisture holding capacity due to shallow soils impedes or stunts the growth of trees or shrubs.

The most extensive glades can be found in Tennessee and Kentucky. Many of the glade soils found in Tennessee and Kentucky were formed in the late Pliocene era when peneplains were uplifted (Braun 1950). These areas encompass large expanses of grassland believed to have been maintained by fire (Baskin and Baskin 1981; Chester 1988; Baskin et al. 1994). Glade communities can be found in several states near and east of the Mississippi River. This includes areas that have been studied in Alabama, Arkansas, Florida, Illinois, Indiana, Missouri, Virginia, and West Virginia. Disturbances are common on many glade sites. Braun (1950) stated that some glades developed on severely eroded sites after logging in the mesophytic forest. Debris avalanches may have created some Appalachian limestone glades (Bartgis 1993). Due to fire suppression and cultivation, Indiana barrens and glades have been reduced to remnants (Bacone et al. 1983). Fire, drought, grazing, and manual removal of trees were historically common in maintaining glades.

Woody plant species are commonly found on limestone glades and barrens. The most common woody species found is eastern redcedar (*Juniperus virginiana*). Associated species include chinkapin oak (*Quercus muhlenbergii*), post oak (*Quercus stellata*), and eastern redbud (*Cercis canadensis*). However, herbaceous species constitute the largest proportion of all plants that are found within limestone glades. Several interacting factors contribute to the high diversity commonly found on limestone glades. These factors include soil infertility, low moisture holding capacity (Tilman 1982), periodic disturbances that prevent single species dominance (Huston 1994), and shallow soils that restrict woody species establishment (Pallardy et al. 1991). Several studies have surveyed species on limestone glades. DeSelm (1993) found 803

species in a survey of Tennessee limestone glades, while Bartgis (1993) found 202 woody and herbaceous species on limestone glades in West Virginia. Baskin et al. (1995) found 269 species on limestone glades in northern Alabama, while a Ludwig (1999) survey found 324 plant species on cedar glades in southwestern Virginia.

Sandstone glades differ significantly from limestone glades. The parent material is obviously different. This will influence any developing soil and the plants that will colonize the site. Sandstone glades are found in locations that have greater relief than limestone glades. Heikens and Robertson (1995) found that sandstone glades are less diverse than limestone glades. Their study showed that sandstone glades have shallower soils, more rocks on the surface, and a much lower pH than limestone glades. Jeffries (1987) found 87 species in sandstone glades in Arkansas, while Hays (1995) found 137 species on sandstone glades in Missouri.

There are some similarities between sandstone and limestone glades. They share similar growing conditions with very xeric sites, and both have limited opportunities for woody plant establishment. Cracks in the bedrock or depressions where soil has been deposited provide the best growing conditions for woody plants. Sandstone glades tend to have more exposed rock and less overall vegetative cover than limestone glades. Sandstone glades are more wooded than limestone glades, and the most common woody species are eastern redcedar, post oak, blackjack oak (*Quercus marilandica*), and winged elm (*Ulmus alata*). The primary factors that have historically maintained sandstone glades are drought, erosion, fire, bedrock weathering, and flooding (Nelson 1985; Hays 1995). These natural disturbances maintain the harsh growing conditions that restrict the colonization of more mesic species.

Rock Outcrop Communities

Rock outcrop communities are characterized by having bedrock at or near the surface, poorly developed soils deficient in nutrients, xeric conditions throughout most of the growing season, poorly developed vegetation, and an abundance of mosses and lichens (Jefferies 1987; Nelson 1985; Quarterman et al. 1993). The most notable research on granite outcrop communities has focused on communities located in the Piedmont of the southeastern United States, starting in northeastern North Carolina and going to eastern Alabama (Oosting and Anderson 1939; Keever et al. 1951; Burbanck and Platt 1964; Wyatt and Fowler 1977; Phillips 1981; Burbanck and Phillips 1983). Areas that have been studied include the west-central and western portions of the Piedmont, with the primary emphasis along the fall-line. The fall-line is the transition found between the Coastal Plain and the Lower Piedmont. This is where the harder crystalline rocks of the Piedmont meet the softer strata of the Coastal Plain, while the western Piedmont outcrops typically occur along the edge of the Blue Ridge escarpment (Wyatt and Fowler 1977). These exposed rock surfaces can range in size from 1 ha up to several hundred hectares (Phillips 1981).

Most research on granite outcrops has focused on "island communities." These communities are depressions containing soil that is completely surrounded by exposed rock. The surrounding rock is granitic and weathers very slowly. The rock surface is smooth and mostly free of crevices. The exposed rock has patches of mosses and crustose lichens. Burbanck and Platt (1964) recognized four different community types: diamorpha communities with soil depths of 2-6 cm, lichen annual herb community with soil depths of 7-15 cm, annual-perennial herb communities with soil depths of 16-39 cm,

and herb-shrub communities with soil depths of 40-50 cm. Rogers (1971) added a fifth outcrop community, which is dominated by trees with a shrubby lower canopy and has soil depths greater than 50 cm. Burbanck and Platt (1964) found 76 species within the "island communities."

Tree species that can be found on rock outcrop communities include eastern redcedar, loblolly pine (*Pinus taeda*), pignut hickory (*Carya glabra*), flowering dogwood (*Cornus florida*), persimmon (*Diospyros virginiana*), and black cherry (*Prunus serotina*). The common sequence of succession begins with mat-building species that catch large amounts of mineral soil as it is blown or washed over them. Lichens then spread over the mats and even more soil is caught. Mosses are then established. Weeds and grasses move in as more mineral soil and organic material accumulate. Woody plants can colonize these sites if the soil layer develops enough to support them (Oosting and Anderson 1939).

The depth of soil appears to be the most important factor in determining what species are present in granite outcrop communities (Phillips 1981; Burbanck and Phillips 1983). With increases in soil depth, there are increases in organic matter, moisture holding capacity, and nutrient holding capacity. Droughts maintain these communities by increasing mortality, which makes them more susceptible to fire, wind, and erosion (Phillips 1981).

Everglades

The term "Everglades" refers to the large freshwater marshlands found in southern Florida. A marsh is a wetland dominated by herbaceous plants that are rooted in, and generally emergent from, shallow water that is present for most of the year

(Kushlan 1990). These marshes begin near Lake Okeechobee and extend almost to the southern tip of the Florida mainland (Lodge 1994). The Everglades are commonly referred to as the "river of grass." The Everglades were originally over 10,000 km^2 in size and had a basin that spanned over 100 km with a slope of only 3.0 cm/km (Kushlan 1990). The fact that the Everglades' water and nutrient inputs are primarily from rainfall without inputs from rivers and streams make it a unique ecosystem. Topography is the principal factor determining the distribution of marshes in southern Florida (White 1970). Water is impounded by topographic rises and coastal ridges that consist primarily of limestone and sand (Kushlan 1990).

Peat, marl, and sand are the three common soil materials found in Florida marshes. Peat is organic soil material in which the original plant material is still recognizable. Peat accumulates in areas that have deep water and long hydroperiods (Duever et al. 1978). The hydroperiod is generally over nine months with very short dry periods. Marl is soft and unconsolidated calcium carbonate, which is the result of periphyton dying during the dry season. Marl is found in marshes that have a moderate hydroperiod with a dry season sufficient to oxidize organic matter (Kushlan 1990). A sand substrate is commonly found on sites with a short hydroperiod and a long dry season.

Defining plant communities within the marshlands of the Everglades is difficult due to the variation in geologic and hydrologic conditions (Lodge 1994). Categories for marsh communities that are generally recognized are sawgrass marshes, wet prairies, sloughs, and ponds and creeks. Sawgrass marshes are areas that are dominated by sawgrass (*Cladium jamaicense*) where plant spacing can vary from sparse to dense (Lodge 1994). Wet prairies are areas where emergent plants other than sawgrass

dominate the community. Sloughs are the deepest marsh communities where the hydroperiod is about 11 months, but can last for several years (Lodge 1994). Ponds, also known as alligator holes, and creeks can be found throughout most of the Everglades. These tend to be open areas of water that are small, but are flooded throughout most of the year. Many of the Florida marshes are dominated by only a few species (Kushlan 1990). However, marshes can be quite diverse. Tanner et al. (1982) found three marshes that contained over 100 species of forbs, grasses, and sedges.

The Florida marshes are maintained by both frequent fires and fluctuating water levels. Fires limit the ability of woody vegetation to colonize marshes, while affecting herbaceous plant community composition (Wade et al. 1980). In addition, fires burn organic material and can reverse peat accumulation. Fire frequency in deep water marshes is between three and five years, while shallow water marshes burn every one to three years (Wade et al. 1980). Fluctuating water levels affect the plant community composition by favoring species that have adapted to the wet conditions and can propagate successfully.

I would like to mention that there are many other plant communities in the Everglades than are mentioned here. Some of the other communities include wetland tree islands, hardwood hammocks, pinelands, and mangrove swamps. These communities were left out of the discussion due to the focus of this section being on the marshlands.

METHODS

Study Area

Camp Brookside, a seasonal island, is located on the floodplain of the New River in Summers County, West Virginia. The property is located 10.3 km downstream from Bluestone Dam and is 10.4 ha in size. The NPS purchased Camp Brookside in 1993. Elkem Metals Company owned the property after World War II and used it as a summer camp for its employees' children. Union Carbide then came into possession of the property and used it as a fishing camp for their employees and guests until 1993.

The NPS has a cooperative agreement with the West Virginia Heritage Program to inventory plant species and communities within park boundaries. The West Virginia Heritage Program has found several rare plant species and a unique riverside FRPC on Camp Brookside. The FRPC is located on the southern end and riverside portion of Camp Brookside and has an overstory of eastern redcedar, Virginia pine, and white ash. The FRPC is characterized by resistant sandstone shelves above water that are generally associated with rapids.

Sampling and Plot Location

Ten transects were established on the southern two-thirds of the island. The northern section of the island was not sampled due to the presence of numerous buildings and maintained openings. The baseline for sampling was set 15 m inland and parallel to the New River, to avoid high water effects and exposed bedrock along the river. The spacing between transects varied between 30.5 and 38 m. Forty-four plot locations were established along transects either 30.5 or 45.75 m apart (Figure 1). The center of each

plot was located using a global positioning system and digitized into an ArcMap geographic information system (GIS) file.

Figure 1. Plot center locations at Camp Brookside, in Summers County, West Virginia.

Forest Vegetation and Site Inventory

Overstory Sampling

A circular 0.04-ha plot was established at each sample point. At each plot species, diameter at breast height (dbh), height, and crown class were recorded for all trees greater than 5 m in height. A healthy dominant or codominant tree in each plot was cored at breast height to determine age. Heights of all overstory trees were measured using a clinometer. Five plant communities were identified in our study at Camp Brookside based on the dominant overstory trees (Figure 2). The dominant overstory trees within the community were identified by having the highest importance values. All measurements were made in the summer of 2000.

Lower Canopy and Shrub Sampling

Trees between 2 and 5 m in height were classified as the lower canopy. Two circular 0.004-ha plots were established 4.5 m on either side of the sample point running parallel to the river. Species identification and dbh were recorded for all tree species, and species and number of individuals were recorded for shrubs.

Regeneration and Ground Cover Sampling

Trees and shrubs from 0-1 m and 1-2 m in height comprised the regeneration stratum. Three 0.0004-ha regeneration plots were established 3 m from each sample point. Two were running parallel to the river, while the third was perpendicular to the river. Species and number of individuals were recorded. Ground cover measurements were taken within each of the regeneration plots. Percent cover of rock, mineral soil, woody debris, herbaceous vegetation, moss/lichen, grass, and organic litter were recorded using visual estimation by cover class.

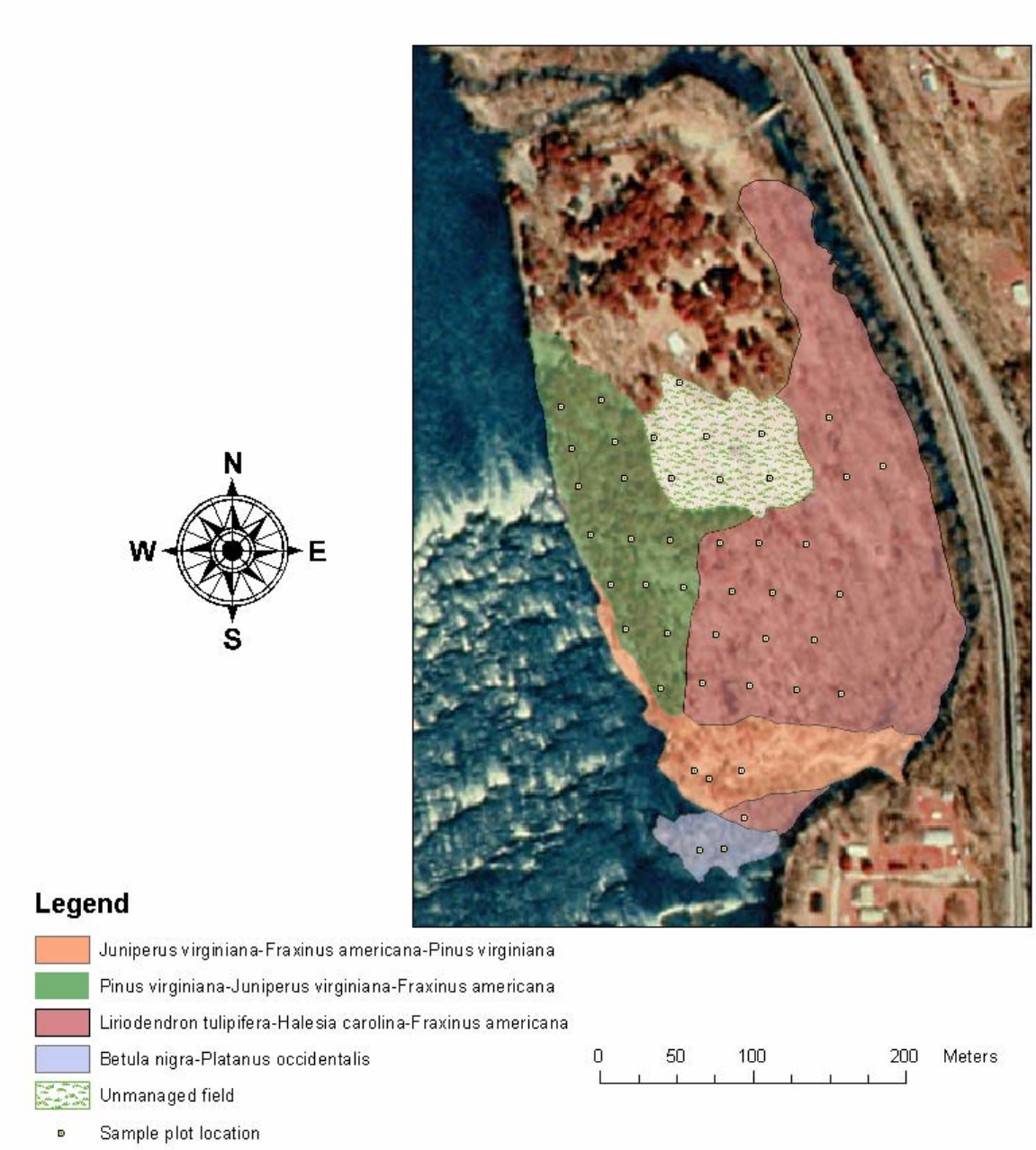

Figure 2. Plant communities at Camp Brookside, in Summers County, West Virginia.

Soil and Forest Litter Sampling

Soil and litter samples were collected from four fixed locations along a transect within each sample plot. Soil samples were collected for two depths: 0-10 cm and 10-20 cm. A composite soil sample for each depth was collected in the field. Depth to bedrock and a general soil description was recorded at each sample location. A composite litter sample was collected from the same four locations where the soil was collected. The litter was collected in 0.092-m^2 sample frames.

Sample Preparation

All soil samples were brought back to the lab and air-dried. The samples were ground with a mortar and pestle to pass through a 2-mm sieve. Coarse fragments (> 2 mm) were collected, washed, and weighed. A sample splitter was used to reduce the samples. The samples were stored in polypropylene bags. All forest litter samples were brought back to the lab and dried to a constant weight in a forced air oven at 65^{o}C. The samples were weighed to the nearest 0.01 g and ground in a Wiley mill to pass through a 1-mm sieve. The samples were put into paper envelopes and stored in a convection oven at 65^{o}C.

Lab Analysis of Soils

The pH was determined in a 2:1 water:soil mixture with a glass electrode (McLean, 1982). Particle-size distribution was determined using the hydrometer method (Day, 1965). Total nitrogen and carbon were determined on an Elementar vario MAX CNS analyzer (Bremner and Mulvaney, 1982). Organic matter content was determined by loss on ignition (McKeague, 1978). A Mehlich double acid extraction was used to extract

phosphorous, potassium, calcium, and magnesium (Mehlich, 1953). Concentrations were determined on a SpectroFlame Modula Tabletop ICP.

Lab Analysis of Forest Litter

Phosphorous, potassium, calcium, and magnesium concentrations of the forest litter were determined on a SpectroFlame Modula Tabletop ICP after dry-ashing (Jones and Steyn, 1973). Total nitrogen and carbon of the forest litter were determined on an Elementar vario MAX CNS analyzer.

Data Analysis

Importance values were calculated for the overstory, lower canopy trees, and lower canopy shrubs. The overstory and lower canopy tree importance values were calculated by (relative density + relative dominance + relative frequency) / 3 for each species. Lower canopy shrub importance values were calculated by (relative density + relative frequency) / 2 for each species. The Shannon-Weiner diversity index is a measure of the diversity of a community. The Shannon-Weiner diversity index was calculated for each community using the following formula:

$$SWDI = \sum_{i=1}^{s} (p_i)(\log_e p_i)$$

where: SWDI = index of species diversity
s = number of species
p_i = proportion of total sample belonging to the *i*th species
$\log_e$ = natural logarithm

RESULTS

Juniperus virginiana-Fraxinus americana-Pinus virginiana (FRPC)

Figure 3. ***Juniperus virginiana-Fraxinus americana-Pinus virginiana*** **plant community.**

This eastern redcedar-white ash-Virginia pine community is the best expression of the FRPC. It is reasonably intact and occupies 0.8 ha. This community had a Shannon-Weiner diversity index (SWDI) of 1.50. Eastern redcedar dominated the overstory in this plant community. Eastern redcedar comprised 2.9 m^2/ha of basal area (57% of the total) and had an importance value of 49%, while Virginia pine comprised 1.4 m^2/ha of basal area (27% of the total) and had an importance value of 25% (Table 1). White ash, the only other species found in the overstory, comprised 0.8 m^2/ha of basal area (16% of the total) and had an importance value of 26%. A complete list of common and scientific names for all trees and shrubs found within the sample plots is located in the Appendix. The ages of overstory dominant or co-dominant trees sampled varied from to 25 to 60 years. The species richness values for all of the communities found on Camp Brookside can be found in Table 2. The overstory for the FRPC had a species richness of 3.

Table 1. Overstory tree characteristics for the *Juniperus virginiana-Fraxinus americana-Pinus virginiana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Average Diameter (cm)	Average Height (m)	Density (stems/ha)	Basal Area (m^2/ha)	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	Importance Value (%)
Eastern redcedar	17.1	8.6	132	2.9	51.6	57.2	37.5	48.7
White ash	10.7	9.5	66	0.8	25.8	15.8	37.5	26.4
Virginia pine	17.0	9.6	58	1.4	22.6	27.0	25.0	24.9
Total			**256**	**5.1**	**100.0**	**100.0**	**100.0**	**100.0**

Table 2. Species richness by plant community for the overstory, lower canopy, shrub, and regeneration layers found at Camp Brookside, Summers County, West Virginia.

Plant Community	Overstory	Lower Canopy	Shrubs	Regeneration (1-2 m)	Regeneration (0-1 m)
Liriodendron tulipifera-Halesia carolina-Fraxinus americana	33	31	5	20	29
Pinus virginiana-Juniperus virginiana-Fraxinus americana	25	27	5	19	23
Juniperus virginiana-Fraxinus americana-Pinus virginiana	3	4	2	1	3
Betula nigra-Platanus occidentalis	8	5	0	0	7
Unmanaged field	3	2	0	0	6

Six species of trees and shrubs were found in the lower canopy (Tables 3 and 4). The lower canopy had 329 tree stems/ha and 329 shrub stems/ha. White ash and eastern redcedar are the prominent tree species growing in the lower canopy, with a cumulative importance value of 67%. The lower canopy had a species richness of 4. Blueberry (V*accinium* spp.) is the prominent shrub growing in the lower canopy, with an importance value of 63%. The shrub layer had a species richness of 2.

Table 3. Lower canopy tree characteristics for the *Juniperus virginiana-Fraxinus americana-Pinus virginiana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Average Diameter (cm)	Density (stems/ha)	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	Importance Value (%)
White ash	2.0	124	37.5	37.8	37.5	37.6
Eastern redcedar	2.8	82	25.0	39.0	25.0	29.7
Virginia pine	1.5	82	25.0	10.1	25.0	20.0
Northern red oak	2.3	41	12.5	13.1	12.5	12.7
Total		**329**	**100.0**	**100.0**	**100.0**	**100.0**

Table 4. Lower canopy shrub characteristics for the *Juniperus virginiana-Fraxinus americana-Pinus virginiana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Density (stems/ha)	Relative Density (%)	Relative Frequency (%)	Importance Value (%)
Blueberry	247	75	50	62.5
St. John's wort	82	25	50	37.5
Total	**329**	**100**	**100**	**100.0**

Virginia pine was the only tree species in the 1-2 m regeneration stratum with 458 tree seedlings/ha (Table 5). Overall estimates of the 0-1 m regeneration stratum show 1,373 tree seedlings/ha. Eastern redcedar had an importance value of 55% and a density of 824 seedlings/ha. The 1-2 m regeneration stratum had a species richness of 1, while the 0-1 m regeneration stratum had a species richness of 3. The ground cover for the FRPC consisted primarily of organic litter (29%), moss/lichens (27%), and herbaceous vegetation (14%) (Table 6).

Table 5. Regeneration characteristics for the *Juniperus virginiana-Fraxinus Americana-Pinus virginiana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Density (stems/ha)	Relative Density (%)	Relative Frequency (%)	Importance Value (%)
1-2 m Regeneration Stratum:				
Virginia pine	458	100.0	100.0	100.0
Total	**458**	**100.0**	**100.0**	**100.0**
0-1 m Regeneration Stratum:				
Eastern redcedar	824	60.0	50.0	55.0
Post oak	275	20.0	25.0	22.5
White ash	275	20.0	25.0	22.5
Total	**1,373**	**100.0**	**100.0**	**100.0**

Table 6. Ground cover estimates by plant community at Camp Brookside, Summers County, West Virginia.

Plant Community	Rock	Mineral Soil	Woody Debris	Organic Litter	Herba-ceous	Moss/ Lichen	Grass	Total
	---------- % ----------							
Liriodendron tulipifera-Halesia carolina-Fraxinus americana	0	3	11	62	21	1	2	**100**
Pinus virginiana-Juniperus virginiana-Fraxinus americana	5	2	8	39	21	16	8	**100**
Juniperus virginiana-Pinus virginiana-Fraxinus americana	12	7	9	29	14	27	2	**100**
Betula nigra-Platanus occidentalis	64	11	7	6	11	2	0	**100**
Unmanaged field	1	2	0	8	20	1	67	**100**

The soil physical and chemical properties for the FRPC can be found in Tables 7 and 8. This plant community had the shallowest soil on the island, with a mean soil depth of 1.8 cm. The textural classification for this community is a loamy sand with a coarse fragment content of 5.1%. This soil had a pH of 3.91, a nitrogen content of 0.62%, and 12.42 % total carbon. The litter physical and chemical properties can be found in Table 9. The mean litter depth was 1.21 cm, with a mean mass of 6,428 kg/ha.

Table 7. Soil physical properties by plant community and depth at Camp Brookside, Summers County, West Virginia.

Plant Community	Soil Depth (cm)	Coarse Fragments (%)	Sand (%)	Silt (%)	Clay (%)	Texture Classification
0-10 cm						
Liriodendron tulipifera-Halesia carolina-Fraxinus americana	48.5	4.6	87	9	4	loamy sand
Pinus virginiana-Juniperus virginiana-Fraxinus americana	17.6	14.1	81	15	5	loamy sand
Juniperus virginiana-Fraxinus americana-Pinus virginiana	1.8	5.1	79	15	6	loamy sand
Betula nigra-Platanus occidentalis	20.6	47.6	78	12	10	sandy loam
Unmanaged field	43.4	4.4	82	14	5	loamy sand
10-20 cm						
Liriodendron tulipifera-Halesia carolina-Fraxinus americana		5.8	86	9	4	loamy sand
Pinus virginiana-Juniperus virginiana-Fraxinus americana		11.8	84	11	5	loamy sand
Betula nigra-Platanus occidentalis		49.6	67	23	10	sandy loam
Unmanaged field		7.3	82	12	5	loamy sand

Table 8. Soil chemical properties by plant community and depth at Camp Brookside, Summers County, West Virginia.

Plant Community	pH	Total N (%)	Anaerobic N (ppm)	Total Carbon (%)	Organic Matter (%)	Available K (kg/ha)	Available Mg (kg/ha)	Available Ca (kg/ha)	Available P (kg/ha)
0-10 cm									
Liriodendron tulipifera-Halesia carolina-Fraxinus americana	5.56	0.18	121	4.12	7.78	30	93	832	7
Pinus virginiana-Juniperus virginiana-Fraxinus americana	4.61	0.25	91	5.83	13.18	25	44	441	6
Juniperus virginiana-Fraxinus americana-Pinus virginiana	3.91	0.62	174	12.42	33.76	10	6	74	3
Betula nigra-Platanus occidentalis	6.53	0.11	90	2.00	4.83	15	45	768	7
Field	5.16	0.13	78	2.78	5.28	54	89	557	6
10-20 cm									
Liriodendron tulipifera-Halesia carolina-Fraxinus americana	5.60	0.11	61	2.87	5.30	28	87	759	7
Pinus virginiana-Juniperus virginiana-Fraxinus americana	4.80	0.12	54	2.69	5.58	20	36	288	5
Betula nigra-Platanus occidentalis	6.45	0.11	73	1.95	5.07	18	53	890	9
Field	5.32	0.08	35	2.00	3.76	40	83	570	5

Table 9. Litter physical and chemical properties by plant community at Camp Brookside, Summers County, West Virginia.

Plant Community	Depth (cm)	Mass (kg/ha)	Total N (%)	Total C (%)	Total K (%)	Total Mg (%)	Total Ca (%)	Total P (%)
Liriodendron tulipifera-Halesia carolina-Fraxinus americana	0.93	9659	1.19	41.55	0.11	0.18	1.50	0.06
Pinus virginiana-Juniperus virginiana-Fraxinus americana	0.83	7754	1.11	48.43	0.08	0.09	1.19	0.05
Juniperus virginiana-Fraxinus americana-Pinus virginiana	1.21	6428	1.39	57.26	0.12	0.11	1.57	0.05
Betula nigra-Platanus occidentalis	0.95	3351	0.98	49.54	0.07	0.07	0.87	0.07
Field	0.71	2207	1.22	41.97	0.14	0.12	0.72	0.07

Pinus virginiana-Juniperus virginiana-Fraxinus americana

Figure 4. ***Pinus virginiana-Juniperus virginiana-Fraxinus americana*** **plant community.**

This community occupies 1.4 ha and is a variant of the FRPC that is undergoing succession toward more tolerant riparian vegetation. This community has a SWDI of 2.8. Virginia pine and eastern redcedar dominate the overstory of this plant community. Virginia pine comprised 11.1 m^2/ha of basal area (56% of total) and had an importance value of 35%, while eastern redcedar comprised 3.7 m^2/ha of basal area (19% of total) and had an importance value of 22% (Table 10). White ash and post oak are the primary canopy associates in this community. Twenty-six percent of the basal area is comprised of deciduous species, mostly riparian in nature. Already, the American sycamore (*Platanus occidentalis*), American elm (*Ulmus americana),* bitternut hickory (*Carya cordiformis*), and white oak (*Quercus alba*) are taller than the Virginia pine and eastern

redcedar. The age of overstory dominant or co-dominant trees sampled varied from 34 to 104 years. The overstory had a species richness of 25 (Table 2).

Table 10. Overstory tree characteristics for the *Pinus virginiana-Juniperus virginiana-Fraxinus americana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Average Diameter (cm)	Average Height (m)	Density (stems/ha)	Basal Area (m^2/ha)	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	Importance Value (%)
Virginia pine	23.4	13.0	301	11.1	33.8	55.3	14.9	34.7
Eastern redcedar	13.6	9.9	280	3.7	31.4	18.4	14.9	21.6
White ash	15.4	11.5	110	2.6	12.4	13.2	13.9	13.1
Post oak	11.6	10.4	35	0.5	3.9	2.6	8.9	5.1
Sugar maple	14.2	11.7	38	0.7	4.3	3.7	5.9	4.6
Downy serviceberry	10.3	9.7	21	0.3	2.4	1.5	7.9	3.9
Northern red oak	10.4	12.6	12	0.1	1.3	0.7	4.0	2.0
Eastern hornbeam	6.0	7.6	8	0.02	0.9	0.1	4.0	1.7
Fringetree	5.2	9.2	10	0.02	1.1	0.1	3.0	1.4
American basswood	6.5	9.4	15	0.05	1.7	0.2	2.0	1.3
Black cherry	5.7	9.2	7	0.02	0.7	0.1	3.0	1.3
Ironwood	5.5	7.4	8	0.02	0.9	0.1	2.0	1.0
Black locust	11.9	10.7	5	0.08	0.6	0.4	2.0	1.0
Bitternut hickory	13.7	13.6	10	0.15	1.1	0.7	1.0	0.9
Red maple	20.7	12.3	7	0.20	0.7	1.1	1.0	0.9
Mockernut hickory	8.6	10.9	5	0.03	0.6	0.1	2.0	0.9
Chestnut oak	8.5	8.4	3	0.02	0.4	0.1	2.0	0.8
White oak	35.7	14.5	2	0.17	0.2	0.8	1.0	0.7
Pawpaw	9.8	4.1	3	0.02	0.4	0.1	1.0	0.5
American elm	17.5	15.1	2	0.04	0.2	0.2	1.0	0.5
American sycamore	15.0	15.3	2	0.03	0.2	0.2	1.0	0.5
Sweet birch	14.7	11.4	2	0.03	0.2	0.1	1.0	0.4
Slippery elm	13.0	11.5	2	0.02	0.2	0.1	1.0	0.4
Shagbark hickory	3.9	7.0	2	0.01	0.2	0.1	1.0	0.4
Tree-of-heaven	4.0	8.7	3	0.01	0.2	0.02	1.0	0.4
Total			**893**	**19.9**	**100.0**	**100.0**	**100.0**	**100.0**

Thirty-two species of trees and shrubs were found in the lower canopy (Tables 11 and 12). The lower canopy had 4,321 tree stems/ha and 608 shrub stems/ha. Fringetree (*Chionanthus virginicus*), eastern redcedar, and northern hackberry (*Celtis occidentalis*) are the prominent tree species growing in the lower canopy, with a cumulative importance value of 44%. Fringetree is commonly found along stream banks as an understory tree and seldom grows to heights greater than 6 m. Fringetree prefers moist soils but can grow in dry woods. Blueberry is the prominent shrub species with an importance value of 51%. The lower canopy had a species richness of 27. The shrub layer had a species richness of 5.

Overall estimates of the 1-2 m regeneration stratum show 1,666 tree and shrub seedlings/ha (Table 13). Leatherwood (*Dirca palustris*), white ash, and fringetree are the prominent tree and shrub species with a cumulative importance value of 43% and a cumulative density of 787 seedlings/ha. Overall estimates of the 0-1 m regeneration stratum show 18,780 tree and shrub seedlings/ha (Table 14). Fringetree, blueberry, sugar maple (*Acer saccharum*), and eastern redcedar are the prominent tree and shrub species, with a cumulative importance value of 44% and a cumulative density of 8,840 seedlings/ha. The 1-2 m regeneration stratum had a species richness of 19, while the 0-1 m regeneration stratum had a species richness of 23. The ground cover of the Virginia pine-eastern red cedar-white ash community consisted primarily of organic litter (39%), herbaceous vegetation (21%), and moss/lichens (16%) (Table 6).

Table 11. Lower canopy tree characteristics for the *Pinus virginiana-Juniperus virginiana-Fraxinus americana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Average Diameter (cm)	Density (stems/ha)	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	Importance Value (%)
Fringetree	1.8	914	21.1	19.4	12.2	17.6
Eastern redcedar	2.3	445	10.3	25.6	11.7	15.9
Northern hackberry	1.3	610	14.1	9.0	8.3	10.5
White ash	1.5	453	10.5	7.8	6.7	8.3
Downy serviceberry	1.8	173	4.0	4.9	7.2	5.4
Smooth blackhaw	2.0	214	5.0	3.8	7.2	5.3
Redbud	2.0	214	5.0	5.9	5.0	5.3
Sugar maple	1.5	288	6.7	2.9	5.6	5.1
Black cherry	1.0	148	3.4	1.2	5.0	3.2
Bitternut hickory	1.8	107	2.5	2.1	5.0	3.2
Ironwood	1.8	156	3.6	2.2	3.3	3.0
Northern red oak	2.3	82	1.9	3.1	3.3	2.8
Post oak	3.1	82	1.9	3.1	2.8	2.6
Virginia pine	3.1	82	1.9	2.9	2.8	2.5
American elm	1.5	49	1.1	0.7	2.2	1.3
Tree of heaven	1.5	74	1.7	0.9	1.1	1.2
Mockernut hickory	1.8	33	0.8	0.7	2.2	1.2
Carolina silverbell	1.3	41	1.0	0.4	1.7	1.0
Eastern hornbeam	2.3	41	1.0	0.9	1.1	1.0
Sassafras	1.8	33	0.8	0.6	0.6	0.7
Black locust	4.8	8	0.2	1.1	0.6	0.6
Red maple	0.8	25	0.6	0.1	1.1	0.6
Shagbark hickory	1.0	16	0.4	0.1	1.1	0.5
Chestnut oak	2.5	8	0.2	0.3	0.6	0.4
American basswood	2.3	8	0.2	0.3	0.6	0.3
Red mulberry	1.0	8	0.2	0.05	0.6	0.3
Slippery elm	0.5	8	0.2	0.01	0.6	0.2
Total		**4,321**	**100.0**	**100.0**	**100.0**	**100.0**

Table 12. Lower canopy shrub characteristics for the *Pinus virginiana-Juniperus virginiana-Fraxinus americana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Density (stems/ha)	Relative Density (%)	Relative Frequency (%)	Importance Value (%)
Blueberry	288	47.3	54.5	50.9
Leatherwood	131	21.6	22.7	22.2
Autumn olive	115	18.9	9.1	14.0
St. John's wort	58	9.5	9.1	9.3
Spicebush	16	2.7	4.5	3.6
Total	**608**	**100.0**	**100.0**	**100.0**

Table 13. Regeneration characteristics for the 1-2m stratum in the *Pinus virginiana-Juniperus virginiana-Fraxinus americana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Density (stems/ha)	Relative Density (%)	Relative Frequency (%)	Importance Value (%)
Leatherwood	366	22.0	9.8	15.9
White ash	220	13.2	14.8	14.0
Fringetree	201	12.1	13.1	12.6
Northern hackberry	128	7.7	9.8	8.8
Sugar maple	146	8.8	6.6	7.7
Black cherry	110	6.6	8.2	7.4
Eastern redcedar	92	5.5	6.6	6.0
Smooth blackhaw	110	6.6	4.9	5.8
Redbud	55	3.3	4.9	4.1
Bitternut hickory	37	2.2	3.3	2.7
Ironwood	37	2.2	3.3	2.7
Tree of heaven	37	2.2	3.3	2.7
American elm	18	1.1	1.6	1.4
Downy serviceberry	18	1.1	1.6	1.4
Eastern hornbeam	18	1.1	1.6	1.4
Mockernut hickory	18	1.1	1.6	1.4
Chestnut oak	18	1.1	1.6	1.4
Flowering dogwood	18	1.1	1.6	1.4
Osage orange	18	1.1	1.6	1.4
Total	**1,666**	**100.0**	**100.0**	**100.0**

Table 14. Regeneration characteristics for the 0-1 m stratum in the *Pinus virginiana-Juniperus virginiana-Fraxinus americana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Density (stems/ha)	Relative Density (%)	Relative Frequency (%)	Importance Value (%)
Fringetree	2855	15.3	12.5	13.9
Blueberry	1977	10.6	10.3	10.4
Sugar maple	2306	12.4	7.4	9.9
Eastern redcedar	1702	9.1	10.3	9.7
Northern hackberry	2251	12.1	4.4	8.2
White ash	1153	6.2	8.8	7.5
Red maple	1483	7.9	6.6	7.3
Leatherwood	1043	5.6	7.4	6.5
Post oak	824	4.4	5.1	4.8
Black cherry	659	3.5	4.4	4.0
Sassafras	549	2.9	2.9	2.9
Ironwood	275	1.5	3.7	2.6
Bitternut hickory	220	1.2	2.9	2.1
Downy serviceberry	329	1.2	2.9	2.1
Tree-of-heaven	275	1.5	2.2	1.8
Virginia pine	220	1.2	1.5	1.3
Redbud	110	0.6	1.5	1.0
Eastern hornbeam	110	0.6	1.5	1.0
Smooth blackhaw	165	0.9	0.7	0.8
Mockernut hickory	110	0.6	0.7	0.7
Black gum	55	0.3	0.7	0.5
Carolina silverbell	55	0.3	0.7	0.5
St. John’s wort	55	0.3	0.7	0.5
Total	**18,780**	**100.0**	**100.0**	**100.0**

The soil physical and chemical properties for the Virginia pine-eastern red cedar-white ash community can be found in Tables 7 and 8. This plant community had an average soil depth of 17.6 cm. The 0-10 cm soil sample had a coarse fragment content of 14.1%, while the 10-20 cm sample had a coarse fragment content of 11.8%. The textural classification for both depths was a loamy sand. The 0-10 cm soil sample had a pH of

4.61, a nitrogen content of 0.25%, and 5.83 % total carbon. The 10-20 cm soil sample had a pH of 4.8, a nitrogen content of 0.12%, and 2.69 % total carbon. The litter physical and chemical properties can be found in Table 9. The mean litter depth was 0.83 cm with a mean mass of 7,754 kg/ha.

Liriodendron tulipifera-Halesia carolina-Fraxinus americana

Figure 5. ***Liriodendron tulipifera-Halesia carolina-Fraxinus americana*** **plant community.**

This riparian forest community is the largest on the island, occupying 3.7 ha. This community had a SWDI of 3.0, which was the highest of all of the communities on the island. Yellow-poplar, Carolina silverbell (*Halesia carolina*), and white ash are the dominant species found in this community. Yellow-poplar comprised 8.7 m^2/ha of basal area (38% of total) and had an importance value of 20% (Table 15). Carolina silverbell comprised 2.0 m^2/ha of basal area (9% of total) and had an importance value of 13%, while white ash comprised 2.0 m^2/ha of basal area (8% of total) and had an importance value of 11%. Bitternut hickory, American sycamore, black cherry, and sugar maple are the primary canopy associates in this community. This community had a species richness of 33, which was the highest of all of the communities (Table 2). The age of dominant or co-dominant trees sampled varied from 34 to 83 years.

Table 15. Overstory tree characteristics for the *Liriodendron tulipifera-Halesia carolina-Fraxinus americana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Average Diameter (cm)	Average Height (m)	Density (stems/ha)	Basal Area (m^2/ha)	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	Importance Value (%)
Yellow poplar	30.7	14.9	94	8.65	14.8	37.5	8.4	20.2
Carolina silverbell	14.6	12.6	142	2.02	22.3	8.7	9.1	13.4
White ash	17.0	12.9	84	1.95	13.2	8.5	10.5	10.7
Bitternut hickory	14.6	12.4	41	0.72	6.4	3.1	7.7	5.7
American sycamore	40.6	14.8	13	1.92	2.0	8.3	4.9	5.1
Black cherry	17.1	10.6	25	0.84	3.9	3.6	4.9	4.1
Sugar maple	18.7	11.4	26	0.76	4.1	3.3	4.9	4.1
Ironwood	10.0	9.7	35	0.25	5.5	1.1	5.6	4.1
Virginia pine	26.2	15.6	22	1.07	3.3	4.6	3.5	3.8
Redbud	8.6	8.6	23	0.20	3.7	0.9	4.9	3.2
American basswood	12.3	11.0	23	0.40	3.7	1.7	3.5	3.0
Northern red oak	18.7	12.7	15	0.44	2.3	1.9	3.5	2.6
Black locust	25.0	12.9	9	0.58	1.4	2.5	3.5	2.5
Eastern redcedar	18.5	12.2	15	0.36	2.3	2.1	2.8	2.4
Sassafras	22.3	14.6	7	0.30	1.1	1.3	2.8	1.7
River birch	39.4	16.4	6	0.71	0.9	3.1	0.7	1.6
White oak	27.7	12.7	4	0.39	0.7	1.7	2.1	1.5
American elm	14.2	11.0	7	0.14	1.1	0.6	2.1	1.3
Persimmon	14.8	11.5	7	0.14	1.1	0.6	1.4	1.0
Black walnut	65.6	15.9	1	0.49	0.2	2.1	0.7	1.0
American beech	27.0	14.6	3	0.26	0.5	1.1	1.4	1.0
Slippery elm	10.5	10.0	9	0.08	1.4	0.3	0.7	0.8
Post oak	13.5	13.6	4	0.06	0.7	0.2	1.4	0.8
Cucumber magnolia	16.4	8.2	3	0.08	0.5	0.3	1.4	0.8
Boxelder	7.0	5.5	4	0.02	0.7	0.1	1.4	0.7
Flowering dogwood	6.2	7.0	3	0.01	0.5	0.04	1.4	0.7
Shagbark hickory	17.6	14.5	3	0.07	0.5	0.31	0.7	0.5
Black oak	31.5	17.1	1	0.11	0.2	0.50	0.7	0.5
Honeylocust	9.1	12.2	1	0.01	0.2	0.04	0.7	0.3
Pawpaw	3.0	5.6	1	0.01	0.2	0.04	0.7	0.3
Mockernut hickory	5.0	7.7	1	0.00	0.2	0.02	0.7	0.3
Red maple	6.0	8.6	1	0.00	0.2	0.02	0.7	0.3
Red mulberry	6.6	7.6	1	0.00	0.2	0.02	0.7	0.3
Total			**634**	**23.05**	**100.0**	**100.0**	**100.0**	**100.0**

Thirty-six species of trees and shrubs were found in the lower canopy (Tables 16 and 17). The lower canopy had 3,733 tree stems/ha and 2,143 shrub stems/ha. Carolina silverbell, sugar maple, white ash, and northern hackberry are the prominent tree species growing in the lower canopy, with a cumulative importance value of 50%. The lower canopy had a species richness of 31. Leatherwood and spicebush (*Lindera benzoin*) are the dominant shrub species, with a cumulative importance value of 92%. The shrub layer had a species richness of 5.

Overall estimates of the 1-2 m regeneration stratum show 1,841 tree and shrub seedlings/ha (Table 18). Spicebush, leatherwood, and white ash are the prominent tree and shrub species, with a cumulative importance value of 47% and a cumulative density of 905 seedlings/ha. Overall estimates of the 0-1 m regeneration stratum show 15,650 tree and shrub seedlings/ha (Table 19). Leatherwood, sassafras (*Sassafras albidum*), sugar maple, and black cherry (*Prunus serotina*) are the prominent tree and shrub species, with a cumulative importance value of 44% and a cumulative density of 7,316 seedlings/ha. The 1-2 m regeneration stratum had a species richness of 20, and the 0-1 m regeneration stratum had a species richness of 29. The ground cover of the yellow poplar-Carolina silverbell-white ash community consisted primarily of organic litter (62%) and herbaceous vegetation (21%) (Table 6).

Table 16. Lower canopy tree characteristics for the *Liriodendron tulipifera-Halesia carolina-Fraxinus americana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Average Diameter (cm)	Density (stems/ha)	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	Importance Value (%)
Carolina silverbell	2.3	676	18.1	19.6	12.6	16.8
Sugar maple	1.5	509	13.6	8.6	11.7	11.3
White ash	2.3	363	9.7	10.8	10.7	10.4
Northern hackberry	2.0	538	14.4	11.6	9.2	11.7
Redbud	2.3	225	6.0	7.2	6.3	6.5
Fringetree	4.8	87	2.3	10.8	2.4	5.2
Black cherry	1.5	174	4.7	2.7	7.3	4.9
Pawpaw	1.3	320	8.6	2.9	2.9	4.8
Ironwood	2.5	116	3.1	4.5	4.4	4.0
Bitternut hickory	1.3	153	4.1	2.1	5.3	3.8
Smooth blackhaw	1.5	116	3.1	2.2	3.9	3.1
Eastern redcedar	2.8	65	1.8	4.1	3.4	3.1
American basswood	2.5	58	1.6	2.2	2.4	2.1
American elm	1.5	58	1.6	0.8	2.9	1.8
Downy serviceberry	2.5	29	0.8	1.3	1.9	1.3
Northern red oak	1.3	44	1.2	0.9	1.9	1.3
White oak	2.0	29	0.8	1.2	1.9	1.3
Yellow poplar	4.1	15	0.4	2.0	1.0	1.1
Sassafras	2.0	29	0.8	0.6	1.5	1.0
Chestnut oak	1.3	36	1.0	0.3	0.5	0.6
Slippery elm	5.1	7	0.2	1.1	0.5	0.6
Flowering dogwood	0.5	15	0.4	.03	1.0	0.5
Black locust	2.5	15	0.4	0.5	0.5	0.5
Sweet cherry	3.3	7	0.2	0.4	0.5	0.4
Hawthorne	3.1	7	0.2	0.4	0.5	0.4
Eastern hornbeam	3.6	7	0.2	0.5	0.5	0.4
Post oak	2.8	7	0.2	0.3	0.5	0.3
Osage orange	2.0	7	0.2	0.2	0.5	0.3
Black gum	1.5	7	0.2	0.1	0.5	0.3
Red maple	1.0	7	0.2	0.1	0.5	0.3
Black walnut	0.8	7	0.2	0.03	0.5	0.2
Total		**3,733**	**100.0**	**100.0**	**100.0**	**100.0**

Table 17. Lower canopy shrub characteristics for the *Liriodendron tulipifera-Halesia carolina-Fraxinus americana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Density (stems/ha)	Relative Density (%)	Relative Frequency (%)	Importance Value (%)
Leatherwood	1206	56.3	44.6	50.5
Spicebush	850	39.7	42.9	41.3
Multiflora rose	73	3.4	8.9	6.2
Witch-hazel	7	0.3	1.8	1.1
St. John's wort	7	0.3	1.8	1.1
Total	**2,143**	**100.0**	**100.0**	**100.0**

Table 18. Regeneration characteristics for the 1-2 m stratum in the *Liriodendron tulipifera-Halesia carolina-Fraxinus americana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Density (stems/ha)	Relative Density (%)	Relative Frequency (%)	Importance Value (%)
Spicebush	404	21.9	16.9	19.4
Leatherwood	339	18.4	16.9	17.7
White ash	162	8.8	10.8	9.8
Carolina silverbell	145	7.9	8.4	8.2
Northern hackberry	178	9.6	6.0	7.8
Redbud	81	4.4	6.0	5.2
Sugar maple	65	3.5	4.8	4.2
Bitternut hickory	65	3.5	4.8	4.2
Black cherry	65	3.5	4.8	4.2
Ironwood	48	2.6	3.6	3.1
Smooth blackhaw	48	2.6	3.6	3.1
Pawpaw	48	2.6	2.4	2.5
Witch-hazel	48	2.6	2.4	2.5
Fringetree	32	1.8	2.4	2.1
Multiflora rose	32	1.8	1.2	1.5
St. John's wort	32	1.8	1.2	1.5
Eastern redcedar	16	0.9	1.2	1.0
Downy serviceberry	16	0.9	1.2	1.0
Flowering dogwood	16	0.9	1.2	1.0
Total	**1,841**	**100.0**	**100.0**	**100.0**

Table 19. Regeneration characteristics for the 0-1 m stratum in the *Liriodendron tulipifera-Halesia carolina-Fraxinus americana* plant community at Camp Brookside, Summers County, West Virginia.

Species	Density (stems/ha)	Relative Density (%)	Relative Frequency (%)	Importance Value (%)
Leatherwood	2762	17.6	15.9	16.8
Sassafras	2471	15.7	7.6	11.6
Sugar maple	1066	6.8	9.7	8.2
Black cherry	1017	6.5	8.3	7.4
Spicebush	1017	6.5	7.6	7.0
Bitternut hickory	1066	6.8	6.9	6.8
Carolina silverbell	969	6.2	6.9	6.5
White ash	775	4.9	6.9	5.9
White oak	1017	6.5	2.1	4.3
Redbud	533	3.4	4.1	3.8
Flowering dogwood	533	3.4	2.8	3.1
Ironwood	291	1.8	3.4	2.6
Pawpaw	485	3.1	2.1	2.6
Fringetree	291	1.8	2.8	2.3
Eastern hornbeam	339	2.2	2.1	2.1
Smooth blackhaw	242	1.5	1.4	1.5
Downy serviceberry	97	1.2	1.4	1.3
Northern hackberry	97	0.6	1.4	1.0
Witch-hazel	97	0.6	0.7	0.7
Privet	97	0.6	0.7	0.7
Eastern redcedar	48	0.3	0.7	0.5
Northern red oak	48	0.3	0.7	0.5
American basswood	48	0.3	0.7	0.5
Chestnut oak	48	0.3	0.7	0.5
Boxelder	48	0.3	0.7	0.5
Black locust	48	0.3	0.7	0.5
Yellow poplar	48	0.3	0.7	0.5
Multiflora rose	48	0.3	0.7	0.5
Total	**15,650**	**100**	**100**	**100**

The soil physical and chemical properties for the yellow poplar-Carolina silverbell-white ash community can be found in Tables 7 and 8. This plant community had the deepest soil on the island, with a mean soil depth of 48.5 cm. The 0-10 cm soil sample had a coarse fragment content of 4.6%, while the 10-20 cm soil sample had a coarse fragment content of 5.8%. The textural classification for both depths was a loamy sand. The 0-10 cm soil had a pH of 5.56, a nitrogen content of 0.18%, and 4.12 % total carbon. The 10-20 cm soil sample had a pH of 5.6, a nitrogen content of 0.11, and 2.87 % total carbon. The litter physical and chemical properties can be found in Table 9. The mean litter depth was 0.93 cm, with a mean mass of 9,659 kg/ha (Table 9).

Betula nigra-Platanus occidentalis

Figure 6. ***Betula nigra-Platanus occidentalis*** **plant community.**

This is a small riparian woodland community located on the southern end of the island that occupies 0.2 ha. This community had a SWDI of 1.3. River birch and American sycamore dominate the overstory of this community. River birch comprised 5.1 m^2/ha of basal area (40% of total) and had an importance value of 35%, while American sycamore comprised 5.9 m^2/ha of basal area (47% of total) and had an importance value of 34% (Table 20). The age of dominant or co-dominant trees sampled varied from 36 to 41 years. This community had an overstory species richness of 8 (Table 2).

Table 20. Overstory tree characteristics for the *Betula nigra-Platanus occidentalis* plant community at Camp Brookside, Summers County, West Virginia.

Species	Average Diameter (cm)	Average Height (m)	Density (stems/ha)	Basal area (m^2/ha)	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	Importance Value (%)
River birch	14.5	9.0	335	5.09	45.8	40.2	20.0	35.3
American sycamore	16.9	10.4	248	5.93	33.9	46.8	20.0	33.6
White ash	11.9	9.5	37	0.41	5.1	3.3	10.0	6.1
Silver maple	10.9	9.9	37	0.35	5.1	2.8	10.0	6.0
Sugar maple	16.4	12.6	25	0.52	3.3	4.1	10.0	5.8
Slippery elm	10.2	9.8	25	0.20	3.4	1.6	10.0	5.0
American elm	10.1	6.6	12	0.10	1.7	0.8	10.0	4.2
Green ash	6.9	7.0	12	0.05	1.7	0.4	10.0	4.0
Total			**731**	**12.65**	**100.0**	**100.0**	**100.0**	**100.0**

Five species of trees were found in the lower canopy (Table 21). The lower canopy had 1,050 tree stems/ha. Silver maple (*Acer saccharinum*) and American sycamore are the dominant tree species growing in the lower canopy, with a cumulative importance value of 53%. The lower canopy had a species richness of 5.

Table 21. Lower canopy tree characteristics for the *Betula nigra-Platanus occidentalis* plant community at Camp Brookside, Summers County, West Virginia.

Species	Average diameter (cm)	Density (stems/ha)	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	Importance Value (%)
Silver maple	4.1	247	23.5	42.9	30.0	32.1
River birch	2.3	247	23.5	18.3	20.0	20.6
American sycamore	3.1	185	17.6	23.8	20.0	20.5
Silky dogwood	1.0	247	23.5	6.9	20.0	16.8
Black willow	2.3	124	11.8	8.1	10.0	10.0
Total		**1,050**	**100.0**	**100.0**	**100.0**	**100.0**

No trees or shrubs were found in the 1-2 m regeneration stratum. The overall estimates of the 0-1 m regeneration stratum show 114,078 tree and shrub seedlings/ha (Table 22). St. John's wort (*Hypericum spp.*) is the dominant shrub present, with 80,719 stems/ha and an importance value of 51%. Silver maple is the dominant tree present with

27,593 stems/ha and an importance value of 28%. The 0-1 m regeneration stratum had a species richness of 7. The ground cover of the river birch-American sycamore community consisted primarily of rock (64%), mineral soil (11%), and herbaceous vegetation (11%) (Table 6).

Table 22. Regeneration characteristics for the *Betula nigra-Platanus occidentalis* plant community at Camp Brookside, Summers County, West Virginia.

Species	Density (stems/ha)	Relative Density (%)	Relative Frequency (%)	Importance Value (%)
St. John's wort	80,719	70.8	31.6	51.2
Silver maple	27,593	24.2	31.6	27.9
River birch	2,883	2.5	15.8	9.2
Red maple	1,647	1.4	5.3	3.4
American sycamore	412	0.4	5.3	2.8
Black willow	412	0.4	5.3	2.8
Boxelder	412	0.4	5.3	2.8
Total	**114,078**	**100.0**	**100.0**	**100.0**

The soil physical and chemical properties for the river birch-American sycamore community can be found in Tables 7 and 8. This plant community had a mean soil depth of 20.6 cm and had the highest coarse fragment content. The 0-10 cm soil sample had a coarse fragment content of 48%, while the 10-20 cm soil sample had a coarse fragment content of 50%. The textural classification for both depths was a sandy loam. The 0-10 cm soil had a pH of 6.53, a nitrogen content of 0.11%, and 2.00 % total carbon. The 10-20 cm soil sample had a pH of 6.45, a nitrogen content of 0.11, and 1.95 % total carbon. The litter physical and chemical properties can be found in Table 9. The mean litter depth was 0.95 cm with a mean mass of 3,351 kg/ha.

Unmanaged Field

Figure 7. Unmanaged field plant community.

This field is located near the center of the island and occupies 0.7 ha. Only one of the seven plots sampled had any overstory trees present at the time of sampling. This community had a SWDI of 1.0, which was the lowest on the island. The other six plots primarily had a ground cover of grass. Black cherry was the dominant overstory tree, with 2.8 m^2/ha of basal area (65% of total) and an importance value of 58% (Table 23). The overstory tree aged in this community was 64 years old. This community had an overstory species richness of 3 (Table 2).

Table 23. Overstory characteristics for an unmanaged field at Camp Brookside, Summers County, West Virginia.

Species	Average Diameter (cm)	Average Height (m)	Density (stems/ha)	Basal Area (m^2/ha)	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	Importance Value (%)
Black cherry	40.8	15.0	21	2.76	75.0	65.0	33.3	57.8
White ash	52.1	15.7	4	0.75	12.5	17.7	33.3	21.2
Red maple	51.6	14.3	4	0.74	12.5	17.3	33.3	21.0
Total			**29**	**4.25**	**100.0**	**100.0**	**100.0**	**100.0**

Virginia pine and sassafras were the only two tree species found in the lower canopy (Table 24). The lower canopy has 70 tree stems/ha with a species richness of 2. The diversity and richness values were the lowest of all the communities. No trees or shrubs were found in the 1-2 m regeneration stratum. The overall estimates of the 0-1 m regeneration stratum show 1,922 tree and shrub seedlings/ha (Table 25). Virginia pine and eastern redcedar are the prominent species, with a cumulative importance value of 53% and a cumulative density of 961 seedlings/ha. The 0-1 m regeneration stratum had a

species richness of 6. The ground cover of the unmanaged field consisted primarily of grass (67%) and herbaceous vegetation (20%) (Table 6).

Table 24. Lower canopy tree characteristics for an unmanaged field at Camp Brookside, Summers County, West Virginia.

Species	Average Diameter (cm)	Density (stems/ha)	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	Importance Value (%)
Sassafras	1.5	35	50.0	82.3	33.3	55.2
Virginia pine	0.8	35	50.0	17.7	66.7	44.8
Total		**70**	**100.0**	**100.0**	**100.0**	**100.0**

Table 25. Regeneration characteristics for an unmanaged field at Camp Brookside, Summers County, West Virginia.

Species	Density (stems/ha)	Relative Density (%)	Relative Frequency (%)	Importance Value (%)
Virginia pine	412	21.4	33.3	27.4
Eastern redcedar	549	28.6	22.2	25.4
Black cherry	412	21.4	11.1	16.3
Autumn olive	275	14.3	11.1	12.7
Downy serviceberry	137	7.1	11.1	9.1
Red maple	137	7.1	11.1	9.1
Total	**1,922**	**100**	**100**	**100**

The soil physical and chemical properties for the unmanaged field can be found in Tables 7 and 8. This plant community had a mean soil depth of 43.4 cm. The 0-10 cm soil sample had a coarse fragment content of 4.4%, while the 10-20 cm soil sample had a coarse fragment content of 7.3%. The textural classification for both depths was a loamy sand. The 0-10 cm soil had a pH of 5.16, a nitrogen content of 0.13%, and 2.78 % total carbon. The 10-20 cm soil sample had a pH of 5.32, a nitrogen content of 0.08%, and 2.00 % total carbon. The litter physical and chemical properties can be found in Table 9. The mean litter depth was 0.71 cm, with a mean mass of 2,207 kg/ha.

DISCUSSION

Soils

Glades, rock outcrop communities, and the FRPC have a large amount of exposed bedrock or gravel, and where soil is present, it tends to be shallow and infertile. The FRPC had an average soil depth of 1.8 cm. Heikens and Robertson (1995) described limestone glades with an average depth of 8.8 cm, and sandstone glades with an average depth of 4.7 cm. Barrens had a deeper average soil depth of 10.4 cm. Baskin et al. (1994) defined limestone cedar glades as having very shallow soil depths of less than 25 cm, while barrens have much deeper soils, generally greater than 100 cm. Baskin et al. (1994) went on to describe limestone cedar glades as having a surface of limestone pavement or gravel, whereas barrens have no exposed rock. Granite rock outcrop communities have a smooth rock surface that is mostly free of crevices. This differs from the glades and the FRPC due to the large amount of vegetation that grows in the cracks or crevices in the bedrock of these communities.

The pH of the soils within these communities relates directly to the parent material and to the vegetation found on the site. The FRPC had a pH of 3.9, which was the lowest on the island. This is due to the acidic nature of the sandstone bedrock and the influence of the Virginia pine needles in the litter layer. Barton and Wallenstein (1997) showed that the pH of a soil generally decreases as the size of Virginia pines increase. Sandstone glades are the most similar to the FRPC, with pH's generally below 5.6 and as low as 4.1 (Jefferies 1985, Jefferies 1987, Heikens and Robertson 1995). Heikens and Robertson (1995) described limestone glades with a pH of 7.8 and barrens with a pH of 5.2. Shure and Ragsdale (1977) found that granite outcrops tend to be acidic, with pH's ranging

from 4.0 to 5.0. The pH of a soil is important due to its effect on microorganism activity and the availability of soil nutrients. Acidic soils tend to have lower amounts of available nitrogen, calcium, magnesium, phosphorus, potassium, and lower numbers of bacteria and actinomycetes (Brady 1984).

The organic matter content, total carbon, and total nitrogen values were much higher for the FRPC than the other communities found on the island. These values are much higher than would be expected for a site that would be considered infertile. Slow decomposition rates due to acidic soils, pine needles high in lignin, and very dry conditions are possible reasons for this. This accumulation of organic materials within the soil will lower its bulk density. This can generate very high estimates of any data that can be expressed on a weight basis. A positive effect of having a high organic matter content is the increased ability to hold moisture as a soil develops and increases in depth (Phillips 1981, Burbanck and Phillips 1983). Heikens and Robertson (1995) showed that sandstone glades had higher organic matter content than limestone glades or barrens. Sandstone glades had 8.5% organic matter, while limestone glades and barrens had 6.5% and 5.1%, respectively.

The available potassium, magnesium, calcium, and phosphorous values for the soils in the FRPC are much lower than in all of the other communities on the island. This is due to the shallow soil and the lower quality of litter incorporated into the soil. The very low calcium value found for the FRPC when compared to other communities is interesting. The dominant tree in the FRPC is eastern redcedar, which is known to have very high calcium concentrations in its foliage (Burns and Honkala 1990). This can be seen in our litter data, where the FRPC has the highest litter calcium concentration. A

combination of having a rapid uptake of most of the available calcium from the soil, wind transporting the needles away from the site, and retranslocation of calcium before the needles are dropped could account for why there is such a small amount of available calcium in the soil. The available phosphorous level for all of the communities on the island is considered low, except for the FRPC's, which is considered very low. Heikens' and Robertson's (1995) results showed that sandstone glades had lower available calcium, magnesium, and potassium than limestone glades or barrens. However, sandstone glade phosphorous levels were more than twice the level of those found in limestone glades and barrens.

Soils increase in depth on the island as one moves from the FRPC to the *Pinus virginiana-Juniperus virginiana-Fraxinus americana* (xeric pine community), then to the *Liriodendron tulipifera-Halesia carolina-Fraxinus americana* (riparian forest plant community). Kucera and Martin (1957) found that limestone glade communities that were forested had deeper soils, and that soil depth was the critical determinant of soil moisture holding capacity. Burbanck and Phillips (1983) stated that more advanced seral stages are found as soil depth increases on granite outcrops. These concepts also hold true for Camp Brookside. The deep sandy soils of the riparian forest were probably deposited during a major flood in 1878. This disturbance corresponds well with the oldest trees that are found on the island. The oldest tree found on the island in this study was 104 years old. On the riparian forest's deeper soils, natural succession was able to progress past the early successional pine stage. However, the FRPC would have been scoured down to bedrock in the flood and is still in an early seral stage today.

Flat Rock Plant Community

The FRPC is most similar to sandstone glades in respect to soil development and the woody plants found in these communities. Both communities share common parent material, harsh growing conditions, and similar growth habitat in cracks and depressions. The FRPC is a very open community with an overstory having a basal area of only 5.1 m^2/ha, with eastern redcedar being the dominant species. Jefferies (1985) found similar results on 25 sandstone glades, with the overstory having an average basal area of only 2.8 m^2/ha with eastern redcedar being the dominant species. There are two significant differences between Jefferies sandstone glades and the FRPC. First, sandstone glades have a much higher percentage of herbaceous ground cover than the FRPC. Jefferies (1985) found an average herbaceous cover of 50%, while the FRPC only had a herbaceous cover of 14%. Second, the FRPC is associated with and maintained by a high-energy river, and Jefferies sandstone glades are not.

Natural forest succession is the driving force that currently endangers the FRPC. Forest succession refers to the development of a community of forest vegetation over time toward a stable composition (Pritchett and Fisher, 1987). The periodic flooding of the New River pre-1950 created and maintained the FRPC by scouring off all of the soil down to the sandstone bedrock. This allowed the establishment of early successional (pioneer) species that could adapt to growing in cracks or depressions in the sandstone where sand or soil had been deposited from flooding. Since the dam was built in 1949, the frequency, intensity, and duration of flooding have been significantly reduced. This has allowed natural weathering, organic matter deposition, and an accumulation of silt

and debris to go unabated for many years, and has formed a shallow soil on many parts of the FRPC.

Today the FRPC is in fair condition, but is declining. The community is considered to be in fair condition due to the large areas within the community that are still bare to almost bare sandstone with sparse vegetation. The establishment of white ash within the overstory and white ash's dominance in the lower canopy is evidence that the community is in decline. Honeysuckle (*Lonicera japonica*), a known invasive species, can be found along the edges of this community. Pockets of grasses, shrubs, and trees can precipitate the accumulation of organic matter and litter within the community by providing an area that can entrap dust, soil, and debris (Pritchett and Fisher, 1987). These pockets of vegetation will grow larger over time, and the soils will gradually deepen. This will allow species with greater nutrient and moisture requirements to gradually invade and out-compete early successional (pioneer) species such as Virginia pine and eastern redcedar (Pritchett and Fisher, 1987).

Historically, a large part of the *Pinus virginiana-Juniperus virginiana-Fraxinus virginiana* plant community was considered to be a FRPC. This area is in a later seral stage than our current FRPC. Evidence of this is the presence of deeper soils and an increased diversity of species within the overstory, lower canopy, and regeneration strata. Flooding the island in order to preserve the FRPC is no longer an option due to the damage it would do to the surrounding community. The Virginia Tech Forestry Department is currently working with the NPS NRGNR studying different methods of setting back succession within the FRPC by using combinations of cutting, fire, and herbicide application. If the NPS NRGNR objective is to preserve the FRPC on

Brookside Island, some type of disturbance regime will need to be periodically maintained. Fire is not a practical management tool in maintaining the FRPC due to the lack of adequate fuel on the site and the sensitivity of eastern redcedar and Virginia pine to fire. Both eastern redcedar and young Virginia pine trees have thin bark that is vulnerable to fire. However, the manual removal of mesic species and the use of direct herbicide application are practical management tools in maintaining the FRPC on Camp Brookside. Yearly inspections of the FRPC could be used to determine when maintenance would be needed.

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APPENDIX

Forest tree and shrub list for Camp Brookside, Summers County, West Virginia.

Common Name	Genus, Species
American basswood	*Tilia americana* L.
American beech	*Fagus grandifolia* Ehrh.
American elm	*Ulmus americana* L.
American syacmore	*Platanus occidentalis* L.
Autumn olive	*Elaeagnus umbellata* Thunb.
Bitternut hickory	*Carya cordiformis* (Wang.) K. Koch
Black birch	*Betula lenta* L.
Black cherry	*Prunus serotina* Ehrh.
Black gum	*Nyssa sylvatica* Marsh.
Black locust	*Robinia pseudoacacia* L.
Black oak	*Quercus velutina* Lam.
Black walnut	*Juglans nigra* L.
Black willow	*Salix nigra* Marsh.
Blueberry	*Vaccinium* spp.
Boxelder	*Acer negundo* L.
Carolina silverbell	*Halesia carolina* L.
Chestnut oak	*Quercus prinus* L.
Cucumber magnolia	*Magnolia acuminata* L.
Deerberry	*Vaccinium stamineum* L.
Downy serviceberry	*Amelanchier arborea* (Michx.f.) Fern
Eastern hornbeam	*Ostrya virginiana* (Mill.) K. Koch
Eastern redcedar	*Juniperus virginiana* L.
Flowering dogwood	*Cornus florida* L.
Fringetree	*Chionanthus virginicus* L.
Green ash	*Fraxinus pennsylvanica* (Vahl) Fern
Hawthorne	*Crataegus* spp.
Honeylocust	*Gleditsia triacanthos* L.
Ironwood	*Carpinus caroliniana* Walt.
Japanese honeysuckle	*Lonicera japonica*
Leatherwood	*Dirca palustris* L.

Common Name	Genus, Species
Mockernut hickory	*Carya tomentosa* (Poir.) Nutt.
Multiflora rose	Rosa multiflora Thunb.
Northern red oak	Quercus rubra L.
Northern hackberry	Celtis occidentalis L.
Osage orange	Maclura pomifera (Raf.) Schneid.
Pawpaw	Asimina triloba (L.) Dunal
Persimmon	Diospyros virginiana L.
Post oak	Quercus stellata Wangenh.
Privet	Ligustrum spp. L.
Red maple	Acer rubrum L.
Red mulberry	Morus rubra L.
Redbud	Cercis canadensis L.
River birch	Betula nigra L.
Sassafras	Sassafras albidum (Nutt.) Nees
Shagbark hickory	Carya ovata (Mill.) K. Koch
Silky dogwood	Cornus amomum Mill.
Silver maple	Acer saccharinum L.
Slippery elm	Ulmus rubra Muhl.
Smooth blackhaw	Viburnum prunifolium L.
Spicebush	Lindera benzoin (L.) Blume
St. John’s wort	Hypericum spp.
Sugar maple	Acer saccharum Marsh.
Sweet cherry	Prunus avium (L.) L.
Tree-of-heaven	Ailanthus altissima (Mill.) Swingle
Virginia pine	Pinus virginiana Mill.
Weeping willow	Salix babylonica L.
White ash	Fraxinum americana L.
White oak	Quercus alba L.
Witch-hazel	Hamamelis virginiana L.
Yellow-poplar	Liriondendron tulipifera L.

VITA

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