

SOIL PHYSICAL AND CHEMICAL PROPERTIES ASSOCIATED WITH FLAT ROCK AND RIPARIAN FOREST COMMUNITIES

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Abstract—Flat Rock forest communities are unique ecosystems found adjacent to some large rivers in the Central and Southern Appalachian Mountains. Characterized by thin, alluvial soils overlying flat, resistant sandstone, these areas are maintained by severe flooding and have unique associated plant systems. With the advent of dams to control flooding in the 20th century, many flat rock communities have declined; these areas have been invaded by both exotic species and traditional riparian trees and shrubs. A flat rock forest community and adjacent riparian forest were studied to determine the soil physical and chemical properties associated with each. Vegetation measurements were made of overstory, understory, and regeneration strata and were related to soil characteristics. Based on these measurements, silvicultural treatments to maintain the principal species in the flat rock community were proposed.

INTRODUCTION

The National Park Service (NPS), New River Gorge National River (NRGRR), has expressed concern about natural plant succession in the riverside flat rock forest community (FRFC) at Camp Brookside, Summers County, WV. Camp Brookside has the largest known concentration of rare plant species within the NRGRR (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 FRFC 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 FRFC. The objectives of this study are to assess the current status of the forest communities found on Camp Brookside, provide baseline data for future comparisons of organic matter accumulation and soil development within the FRFC, and provide recommendations for silvicultural treatments to maintain the principal species in the FRFC.

METHODS

Camp Brookside, a seasonal island, is located on the floodplain of the New River in Summers County, WV. The property is located 10.3 km downstream from Bluestone Dam and is 10.4 ha in size. In the spring of 2000, 10 transects with 44 sample locations were established on the island. A circular 0.04-ha plot was established for overstory sampling at each sample point. Species, diameter at breast height (d.b.h.), and crown class were recorded for all trees > 5 m in height. The plant communities were identified based on the dominant overstory tree species. The dominant overstory trees within the community were identified by having the highest importance values (IVs). One healthy dominant or codominant tree in each plot was cored at breast height to determine age.

Soil and litter samples were collected from four fixed locations along a transect within each sample plot. Soil samples were collected for 2 depths: 0 to 10 cm and 10 to 20 cm.

A composite soil sample for each depth was collected in the field. A composite litter sample was collected from the same four locations where the soil was collected.

DATA ANALYSIS

IVs were calculated for the overstory and lower canopy trees (Mueller-Dombois and Ellenberg 1974). The overstory and lower canopy tree IVs were calculated by [(relative density + relative dominance + relative frequency)/3] for each species. The Shannon-Weiner diversity index (SWDI) is a measure of the diversity of a community. The SWDI 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 ith species

log_e = natural logarithm

RESULTS

Three distinct plant communities were identified in our study at Camp Brookside. The best expression of the flat rock forest community is the eastern redcedar (*Juniperus virginiana* L.)-white ash (*Fraxinus americana* L.)-Virginia pine (*Pinus virginiana* Mill.) community which occupies 0.8 ha. Vegetation in the flat rock forest community grows in cracks or depressions where soil and organic material have accumulated. Eastern redcedar is the dominant species in the overstory of this community. Eastern redcedar comprised 2.0 m²/ha of basal area (57 percent of the total) and had an IV of 49 percent, while Virginia pine comprised 1.4 m²/ha of basal area (27 percent of total) and had an IV of 25 percent (table 1). The overstory has a density of 256 stems/ha. The lower canopy is dominated by white ash and eastern redcedar with a cumulative IV of 67 percent (table 2). Overstory tree ages within this

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Table 1—Overstory tree characteristics for the flat rock forest community at Camp Brookside, Summers County, WV

Species	Average diameter	Average height	Density	Basal area	Relative density	Relative dominance	Relative frequency	Importance value
	<i>cm</i>	<i>m</i>	<i>stems/ha</i>	<i>m²/ha</i>	----- percent -----			
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—Lower canopy tree characteristics for the flat rock forest community at Camp Brookside, Summers County, WV

Species	Average diameter	Density	Relative density	Relative dominance	Relative frequency	Importance value
	<i>cm</i>	<i>stems/ha</i>	----- percent -----			
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

community ranged from 25 to 60 years. This community has a SWDI of 1.5. A complete list of common and scientific names for all trees and shrubs found within the sample plots is located in the appendix.

Soil physical and chemical properties for each of the three communities can be found in table 3. The FRFC had the shallowest soil on the island, with a mean soil depth of 1.8 cm. The textural classification for this community is loamy sand. The soil had a pH of 3.91, a total carbon content of 12.42 percent, and a nitrogen content of 0.62 percent. These values for nitrogen and carbon are much higher than would be expected for a site that would be considered infertile. Reasons for these high values include slow decomposition rates due to acidic soils, pine needles high in lignin, and very dry conditions.

The xeric pine forest community is dominated by Virginia pine, eastern redcedar, and white ash. This community is also a FRFC but is undergoing succession toward more tolerant, riparian forest vegetation. This community occupies 1.4 ha. Virginia pine is the dominant overstory tree in this community;

it comprised 11.1 m²/ha of basal area (56 percent of total) and had an IV of 35 percent, while eastern redcedar comprised 3.7 m²/ha of basal area (10 percent of total) and had an IV of 22 percent (table 4). Twenty-six percent of the basal area in this community is comprised of deciduous species, mostly riparian in nature. The overstory has a density of 893 stems/ha. Twenty-seven tree species were found in the lower canopy. Fringetree (*Chioanthus virginicus* L.), eastern redcedar, and northern hackberry (*Celtis occidentalis* L.) are the prominent tree species growing in the lower canopy, with a cumulative IV of 44 percent (table 5). Overstory tree ages within this community ranged from 34 to 104 years. This community has a SWDI of 2.8. The xeric pine community has a mean soil depth of 17.6 cm. The texture classification for this community is loamy sand. The soil has a pH of 4.61, a total carbon content of 5.83, and a nitrogen content of 0.25 (table 3).

The largest forest community on Camp Brookside is a riparian forest which occupies 3.7 ha. Yellow poplar (*Liriodendron tulipifera* L.), Carolina silverbell (*Halesia carolina* L.), and white ash are the dominant species found in this community.

Table 3—Soil physical and chemical properties by plant community at Camp Brookside, Summers County, WV

Plant community	Soil depth	Coarse fragments	Texture classification	Total carbon	Total nitrogen
	<i>cm</i>	<i>percent</i>		--- percent ---	
Riparian forest	48.5	4.6	Loamy sand	4.12	0.18
Xeric pine forest	17.6	14.1	Loamy sand	5.83	0.25
Flat rock forest	1.8	5.1	Loamy sand	12.42	0.62

Table 4—Overstory tree characteristics for the xeric pine forest community at Camp Brookside, Summers County, WV

Species	Average dbh	Average height	Density	Basal area	Relative density	Relative dominance	Relative frequency	Importance value
	cm	m	stems/ha	m ² /ha	----- percent -----			
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

Yellow poplar comprised 8.7 m²/ha of basal area (38 percent of total) and had an IV of 20 percent (table 6). Carolina silverbell comprised 2.0 m²/ha of basal area (8 percent of total) and had an IV of 13 percent, while white ash comprised 2.0 m²/ha of basal area (8 percent of total) and had an IV of 11 percent. Bitternut hickory [*Carya cordiformis* (Wang.) K. Koch], American sycamore (*Platanus occidentalis* L.), black cherry (*Prunus serotina* Ehrh.), and sugar maple (*Acer saccharum* Marsh.) are the primary canopy associates in this community. The overstory has a density of 634 stems/ha. Carolina silverbell, sugar maple, white ash, and northern hackberry are the prominent tree species growing in the lower canopy, with a cumulative IV of 50 percent (table 7). Overstory tree ages within this community ranged from 34 to 83 years. It had a SWDI of 3.0, which is the highest of all of the communities on the island. This community had the deepest soil on the island, with a mean soil depth of 48.5 cm; the texture classification is loamy sand. The soil has a pH of 5.56, a total carbon content of 4.12, and a nitrogen content of 0.18 (table 3).

DISCUSSION

Today the FRFC is in fair condition but is declining. The community is considered to be in fair condition due to the large areas within it 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 community edges. Historically, a large part of the xeric pine forest community was considered to be a FRFC. The xeric pine forest community gives us a glimpse of what the FRFC will look like in the future if no disturbance regime is implemented to preserve it. Soil will continue to develop and deepen, and there will be an increase in the diversity of species within the overstory, lower canopy, and regeneration strata. Flooding the island is no longer an option due to the damage it would cause to the surrounding community, and fire is not a practical management tool due to the lack of adequate fuel on the site and the sensitivity of eastern redcedar and Virginia pine to fire.

RECOMMENDATIONS

The manual removal of mesic species and the use of direct herbicide application are practical management tools in maintaining the FRFC at Camp Brookside. This area will need to be monitored by NPS personnel to determine when this disturbance regime will need to be periodically implemented.

Table 5—Lower canopy tree characteristics for the xeric pine forest community at Camp Brookside, Summers County, WV

Species	Average dbh	Density	Relative density	Relative dominance	Relative frequency	Importance value
	<i>cm</i>	<i>stems/ha</i>	----- percent -----			
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 6—Overstory tree characteristics for the riparian forest community at Camp Brookside, Summers County, WV

Species	Average dbh	Average height	Density	Basal area	Relative density	Relative dominance	Relative frequency	Importance value
	<i>cm</i>	<i>m</i>	<i>stems/ha</i>	<i>m²/ha</i>	----- percent -----			
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

Table 7—Lower canopy tree characteristics for the riparian forest community at Camp Brookside, Summers County, WV

Species	Average dbh	Density	Relative density	Relative dominance	Relative frequency	Importance value
	<i>cm</i>	<i>stems/ha</i>	----- percent -----			
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

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Appendix—Forest tree and shrub list for Camp Brookside, Summers County, WV

Common name	Genus, species	Common name	Genus, species
American basswood	<i>Tilia americana</i> L.	Mockernut hickory	<i>Carya tomentosa</i> (Poir.) Nutt.
American beech	<i>Fagus grandifolia</i> Ehrh.	Multiflora rose	<i>Rosa multiflora</i> Thunb.
American elm	<i>Ulmus americana</i> L.	Northern red oak	<i>Quercus rubra</i> L.
American sycamore	<i>Platanus occidentalis</i> L.	Northern hackberry	<i>Celtis occidentalis</i> L.
Autumn olive	<i>Elaeagnus umbellata</i> Thunb.	Osage orange	<i>Maclura pomifera</i> (Raf.) Schneid.
Bitternut hickory	<i>Carya cordiformis</i> (Wang.) K. Koch	Pawpaw	<i>Asimina triloba</i> (L.) Dunal
Black birch	<i>Betula lenta</i> L.	Persimmon	<i>Diospyros virginiana</i> L.
Black cherry	<i>Prunus serotina</i> Ehrh.	Post oak	<i>Quercus stellata</i> Wangenh.
Black gum	<i>Nyssa sylvatica</i> Marsh.	Privet	<i>Ligustrum spp.</i> L.
Black locust	<i>Robinia pseudoacacia</i> L.	Red maple	<i>Acer rubrum</i> L.
Black oak	<i>Quercus velutina</i> Lam.	Red mulberry	<i>Morus rubra</i> L.
Black walnut	<i>Juglans nigra</i> L.	Redbud	<i>Cercis canadensis</i> L.
Black willow	<i>Salix nigra</i> Marsh.	River birch	<i>Betula nigra</i> L.
Blueberry	<i>Vaccinium spp.</i>	Sassafras	<i>Sassafras albidum</i> (Nutt.) Nees
Boxelder	<i>Acer negundo</i> L.	Shagbark hickory	<i>Carya ovata</i> (Mill.) K. Koch
Carolina silverbell	<i>Halesia carolina</i> L.	Silky dogwood	<i>Cornus amomum</i> Mill.
Chestnut oak	<i>Quercus prinus</i> L.	Silver maple	<i>Acer saccharinum</i> L.
Cucumber magnolia	<i>Magnolia acuminata</i> L.	Slippery elm	<i>Ulmus rubra</i> Muhl.
Deerberry	<i>Vaccinium stamineum</i> L.	Smooth blackhaw	<i>Viburnum prunifolium</i> L.
Downy serviceberry	<i>Amelanchier arborea</i> (Michx.f.) Fern	Spicebush	<i>Lindera benzoin</i> (L.) Blume
Eastern hornbeam	<i>Ostrya virginiana</i> (Mill.) K. Koch	St. John's wort	<i>Hypericum spp.</i>
Eastern redcedar	<i>Juniperus virginiana</i> L.	Sugar maple	<i>Acer saccharum</i> Marsh.
Flowering dogwood	<i>Cornus florida</i> L.	Sweet cherry	<i>Prunus avium</i> (L.) L.
Fringetree	<i>Chionanthus virginicus</i> L.	Tree-of-heaven	<i>Ailanthus altissima</i> (Mill.) Swingle
Green ash	<i>Fraxinus pennsylvanica</i> (Vahl) Fern	Virginia pine	<i>Pinus virginiana</i> Mill.
Hawthorne	<i>Crataegus spp.</i>	Weeping willow	<i>Salix babylonica</i> L.
Honeylocust	<i>Gleditsia triacanthos</i> L.	White ash	<i>Fraxinus americana</i> L.
Ironwood	<i>Carpinus caroliniana</i> Walt.	White oak	<i>Quercus alba</i> L.
Japanese honeysuckle	<i>Lonicera japonica</i>	Witch-hazel	<i>Hamamelis virginiana</i> L.
Leatherwood	<i>Dirca palustris</i> L.	Yellow-poplar	<i>Liriodendron tulipifera</i> L.