COMMONWEALTH of VIRGINIA

THIRTEEN YEARS OF ECOLOGICAL CHANGE ON BULL RUN MOUNTAIN, VIRGINIA 2001-2014

Results of permanent vegetation plot resampling and implications for natural area stewardship

Virginia Department of Conservation and Recreation
Division of Natural Heritage
Richmond, Virginia

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CONSERVING VIRGINIA'S NATURAL AND RECREATIONAL RESOURCES

THIRTEEN YEARS OF ECOLOGICAL CHANGE ON BULL RUN MOUNTAIN, VIRGINIA 2001 - 2014

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Fig. 1. Catletts Branch and mature hardwood forest with American Beech, April 3, 2014

INTRODUCTION

In May of 2002, the Bull Run Mountains Natural Area Preserve was formally dedicated as the 34th State Natural Area Preserve, protecting many of this area's special habitats and high-quality forests. Although located in the rolling Piedmont physiographic region of northern Virginia, the Bull Run Mountains constitute a monadnock-like set of isolated ridges that rises considerably higher than the surrounding landscape. Their sharp ridges and deep valleys contain habitats, flora, and fauna that have strong affinities to the main Appalachian ranges to the west and that are essentially disjunct in the Piedmont. Virginia Outdoors Foundation (VOF), a state agency, owns the majority of the 1000-hecatre (2486-acre) preserve and manages all of it. However, a 205-acre tract on High Point Mountain is privately owned by Roland Farms, Inc. The Virginia Department of Conservation and Recreation's Division of Natural Heritage (DCR-DNH) holds the deed of dedication on the entire preserve, has an advisory role in management, and provides technical assistance. A third organization, the Bull Run Mountains Conservancy (BRMC), provides interpretive and educational programs that are focused on the mountain and is headquartered at the entrance to the 800-acre southern portion of the preserve open to public access. A fourth organization, the Potomac Appalachian Trail Club (PATC), provides technical assistance with the trail system throughout the preserve.

Prior to the natural area dedication, the area's vascular flora, bryophytes, lichens, and some fauna had been the subjects of intensive scientific and biological research for decades, and the site had been extensively scrutinized for protection from development (Allard and Leonard 1943, 1944a, 1944b, 1952; National Park Service 1965; Abbot Associates 1972; Racine 1978; Stovall 1980; Martin 1993 and unpublished data; Earth Design Associates Inc. 1997; Fleming et al. 1999). Yet despite all the attention given to the Bull Run Mountains by biologists and land planners of various disciplines, the area's ecological communities and the environmental factors associated with them had never been defined in a systematic, quantitative way. Therefore, in 2001, DCR-DNH ecologists conducted a comprehensive inventory of natural vegetation throughout the Bull Run Mountains area. A primary purpose of the 2001 study was to provide a more rigorous classification of natural communities, based on field-collected data and analysis. These data, in turn, would be valuable for providing baseline information to guide stewardship of, and specific management decisions for, the new Natural Area Preserve. In addition, the information could help inform ongoing conservation activities by VOF and provide guidance to the area's many private property owners who care deeply about their land and the future of the region.

As part of the 2001 study, 72 quantitative vegetation plots were sampled across the full range of site conditions, including geologic substrate, aspect, elevation, and local topography. Plots consisted of 400m^2 quadrats and were sampled using the relevé method (sensu Peet *et al.* 1998), following standard procedures employed by DCR-DNH (Virginia Dept. of Conservation and Recreation, 2011). In order to facilitate monitoring of long-term environmental and vegetation changes, 45 of the plots were marked with aluminum tree tags so that they could be relocated and resampled in the future. Within each plot, the presence and cover of all vascular plant species were recorded, along with data on the vertical stratification of cover and the diameters at breast height (DBH) of all woody species ≥ 2.5 cm (one inch) DBH. The total vegetative cover in each height stratum was also recorded, and standard woody stem density and basal area were calculated for each plot. A standard set of environmental data was measured or estimated at each plot, and soil samples were collected for chemical analysis in the laboratory. Evidence of past and ongoing disturbance was also recorded. The compositional data were entered into a database and analyzed using hierarchical agglomerative cluster analysis implemented in the software program PC-ORD (McCune and Mefford 1999). Based on the results of this analysis, ten association-level community types containing plots with similar floristic composition were identified.

The ordination method non-metric multidimensional scaling (NMDS; Kruskal 1964) was used to validate the classification and identify the environmental gradients along which the community types were distributed. See Fleming (2002) for a detailed report on this study and its results.

In 2012 Eagle Scouts, under the supervision of BRMC, installed deer exclosures around two of the 2001 plots in the 800-acre public access area north of Thoroughfare Gap. For several decades, a growing population of white-tailed deer had been exerting heavy selective grazing pressure on both herbaceous and low woody plants throughout the preserve (Fleming 2002). The exclosures were constructed around two plots that in 2001 had relatively high floristic diversity and many palatable forbs favored by deer. In order to provide baseline data for assessing changes in the deer-excluded habitat going forward, the two plots were resampled by DCR-DNH on June 20, 2012. A subsequent comparison of data from the 2001 sampling with that collected in 2012 revealed that profound changes had taken place in these quadrats over little more than a decade. Given the magnitude of the changes, plans were made to relocate and resample more of the 2001 plots.

On several dates in March and April of 2014, reconnaissance was conducted to relocate the remaining 43 plots that had been marked with tree tags. This proved more difficult than anticipated, as some of the tag trees had blown down, and other tags had fallen off or could not be found. Nevertheless, aided by tree data and descriptions from 2001, 38 of the 43 plots were relocated and selected for resampling. Of the 40 plots resampled (including the two in 2012), 27 are located on the Natural Area Preserve and 13 are located on private lands adjacent to the preserve. The resampling was conducted on 11 dates in May, June, July, August, and September of 2014.

The results of the resampling study, enumerating a number of ongoing and new changes in the area's forests and vegetation, are presented in this document. In the years since the 2002 ecological study report and a management plan for the preserve (Leahy and Erdle 2004) were written, both biological changes and increased public access have created difficult management challenges and led VOF to plan a series of multi-organizational meetings among stakeholders to hash out long-term operational, public access, and management issues. It is hoped that the findings of the current study will provide some guidance and general recommendations on biological stewardship for consideration in these upcoming planning sessions.

METHODS

The plots were resampled using standard DCR-DNH methods that replicate those used in 2001 (Fleming 2002), except that soil samples were not collected again. In addition, the plots were monumented with 24" rebar stakes painted light blue and sunk approximately 18" at all four corners. The use of tree tags and bearing lines often proved to be somewhat imprecise in achieving an exact reconstruction of a plot. The use of more permanent rebar secured in the ground at each plot corner (Plate 1) will ensure that future resampling captures precisely the same quadrat. Tree tags that remain were also left in place (Plate 2). A list of the 40 permanent plots is provided in Table 1 and their general location mapped in Figure 1. See the Appendix for detailed location maps.

Data on floristic composition, environmental variables, disturbance, vertical structure, and woody stem tallies were entered into the VaPLOTS database and exported along with the 2001 data in tabular form for analysis. Assessments of differences between the 2001 and 2014 samples were conducted by directly comparing the compositional data, environmental data, information on disturbance, stem density, and basal area for each pair of plots. The plots were then aggregated into five vegetation groups so that changes in composition, structure, and disturbance regimes could be analyzed to detect broader trends:

1 – Seepage Swamps group (5 plots)
2 – Mesic Forests group (5 plots)
3 – Oak – Hickory and Mixed Oak Forests group (14 plots)
4 – Oak / Heath Forests group (10 plots)
5 – Pine – Oak / Heath Woodlands group (6 plots)

Limitations of time and resources precluded more intensive quantitative comparisons of data. However, for the purposes of stewardship and management planning, results from this more limited analysis should still have ample utility. All plot data is archived at DCR-DNH and is available on request.

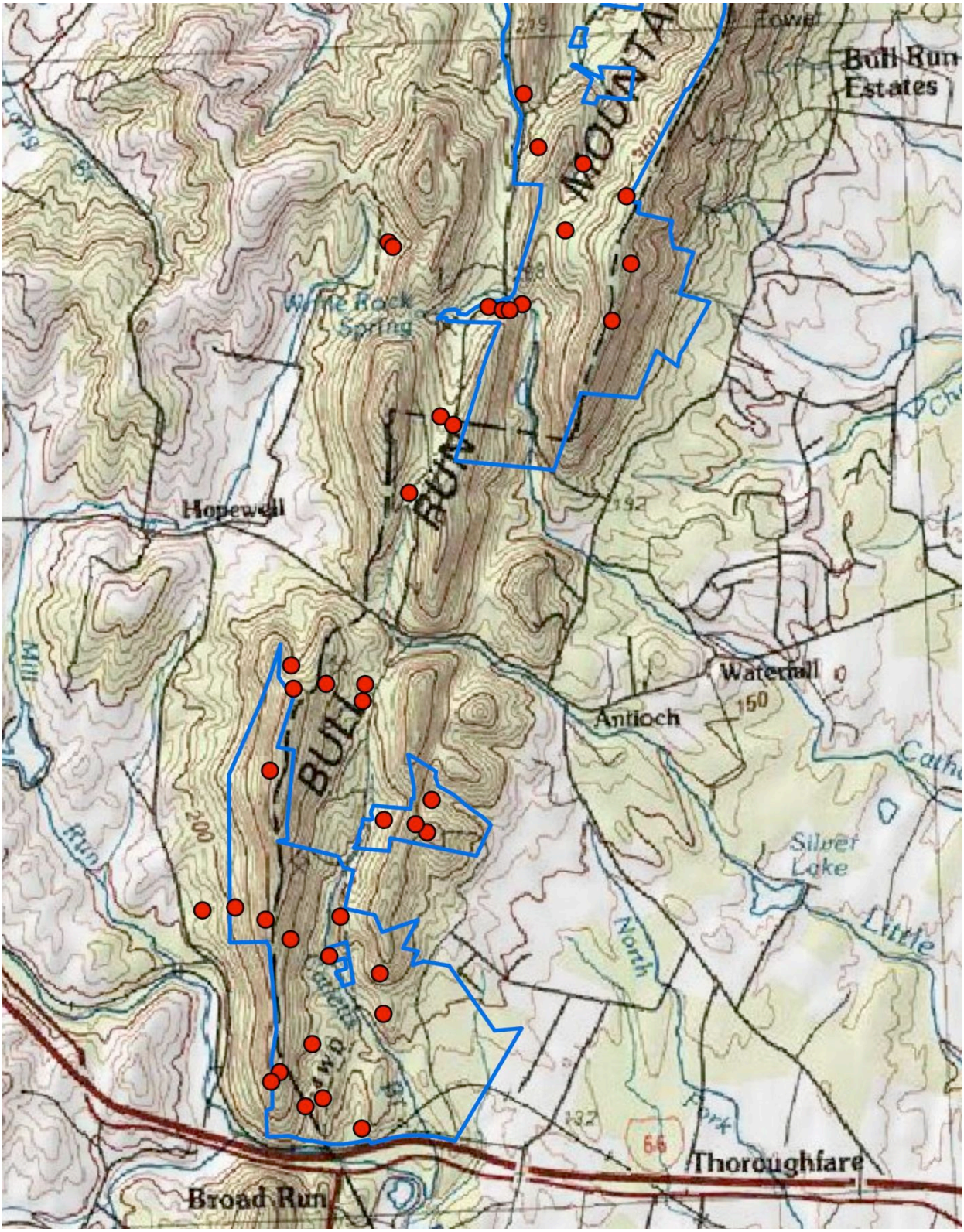
Plate 1. Rebar corner stake. BULL034R.

Plate 2. Tree tag from 2001. BULL034R.

Table 1. List of permanent plots resampled in 2012 and 2014.

Date	Plot	General Location	County	In NAP?	Vegetation Group
6/20/2012	BULL007R	Thoroughfare Gap (Fern Hollow)	Prince William	yes	Mesic Forests
5/28/2014	BULL012R	Jackson Hollow headwaters	Fauquier	no	Seepage Swamps
5/28/2014	BULL014R	Little Bull Run headwaters	Fauquier	no	Seepage Swamps
6/6/2014	BULL015R	Hungry Run headwaters	Fauquier	yes	Seepage Swamps
5/29/2014	BULL016R	Middle Ridge north of Hopewell Gap	Fauquier	yes	Oak - Hickory and Mixed Oak Forests
5/28/2014	BULL017R	Jackson Hollow	Fauquier	yes	Mesic Forests
6/10/2014	BULL018R	Catletts Branch headwaters	Fauquier	no	Oak - Hickory and Mixed Oak Forests
6/10/2014	BULL019R	Catletts Branch headwaters	Fauquier	no	Oak / Heath Forests
5/29/2014	BULL020R	Thoroughfare Gap	Prince William	yes	Oak / Heath Forests
7/17/2014	BULL021R	High Point Mtn (east slope)	Prince William	yes	Oak - Hickory and Mixed Oak Forests
9/18/2014	BULL022R	High Point Mtn (crest)	Fauquier	yes	Pine - Oak / Heath Woodlands
7/17/2014	BULL023R	Thoroughfare Gap	Prince William	yes	Oak / Heath Forests
7/17/2014	BULL024R	Thoroughfare Gap (Quarry Ridge)	Prince William	yes	Pine - Oak / Heath Woodlands
6/17/2014	BULL025R	East Ridge south of Hopewell Gap	Prince William	yes	Pine - Oak / Heath Woodlands
6/17/2014	BULL026R	East Ridge south of Hopewell Gap	Prince William	yes	Mesic Forests
6/17/2014	BULL027R	East Ridge south of Hopewell Gap	Prince William	yes	Oak / Heath Forests
7/16/2014	BULL030R	East Ridge north of Hopewell Gap	Prince William	yes	Oak - Hickory and Mixed Oak Forests
7/16/2014	BULL031R	East Ridge north of Hopewell Gap	Prince William	yes	Oak - Hickory and Mixed Oak Forests
9/18/2014	BULL032R	East Ridge north of Hopewell Gap	Fauquier	yes	Pine - Oak / Heath Woodlands
8/7/2014	BULL034R	Middle Ridge north of Hopewell Gap	Fauquier	no	Oak / Heath Forests
7/16/2014	BULL035R	East Ridge north of Hopewell Gap	Fauquier	yes	Pine - Oak / Heath Woodlands
5/29/2014	BULL036R	Jackson Hollow	Fauquier	yes	Mesic Forests
6/10/2014	BULL037R	Jackson Hollow	Fauquier	yes	Oak - Hickory and Mixed Oak Forests
6/17/2014	BULL038R	East Ridge south of Hopewell Gap	Fauquier	yes	Oak - Hickory and Mixed Oak Forests
5/30/2014	BULL043R	High Point Mtn (west slope)	Fauquier	yes	Oak - Hickory and Mixed Oak Forests
5/30/2014	BULL044R	High Point Mtn (east slope)	Fauquier	no	Oak - Hickory and Mixed Oak Forests
5/29/2014	BULL047R	Middle Ridge north of Hopewell Gap	Fauquier	yes	Oak / Heath Forests
6/16/2014	BULL049R	Catletts Branch	Prince William	no	Oak / Heath Forests
6/16/2014	BULL050R	East Ridge no. of Thoroughfare Gap	Prince William	yes	Pine - Oak / Heath Woodlands
6/16/2014	BULL051R	East Ridge no. of Thoroughfare Gap	Prince William	yes	Oak / Heath Forests
6/16/2014	BULL052R	Catletts Branch	Prince William	yes	Oak - Hickory and Mixed Oak Forests
5/30/2014	BULL058R	High Point Mtn (west slope)	Fauquier	no	Oak - Hickory and Mixed Oak Forests
5/30/2014	BULL059R	High Point Mtn (north end)	Fauquier	no	Mesic Forests
8/7/2014	BULL064R	Middle Ridge north (Sheuters Hill)	Fauquier	yes	Oak / Heath Forests
6/6/2014	BULL065R	High Acre Ridge (base)	Fauquier	no	Seepage Swamps
6/6/2014	BULL067R	High Acre Ridge (base)	Fauquier	no	Oak - Hickory and Mixed Oak Forests
5/28/2014	BULL068R	High Point Mtn (base)	Fauquier	no	Seepage Swamps
6/6/2014	BULL069R	High Point Mtn (west slope)	Fauquier	yes	Oak - Hickory and Mixed Oak Forests
6/20/2012	BULL071R	High Point Mtn (east slope)	Fauquier	yes	Oak - Hickory and Mixed Oak Forests
7/17/2014	BULL072R	High Point Mtn (crest)	Fauquier	no	Oak / Heath Forests

Figure 1. General location of 40 permanent vegetation plots resampled in 2012-2014. The plots are indicated by red dots and the Natural Area Preserve boundaries are shown in blue. See the Appendix for detailed location maps.



RESULTS

Results are organized by vegetation group (see p. 7). A brief summary of conditions in each group is given, followed by a discussion of each plot in that group. We have included this more detailed plot-by-plot narrative because it will be useful in the future if these plots are resampled again. In addition, it provides information about specific localities that can be identified using the maps in the Appendix. Note that the base codes (BULLxxx) for the original and resampled plots are the same; 2001 plot codes have the suffix "P" (permanent), and the 2012-2014 plot codes have the suffix "R" (resample).

SEEPAGE SWAMPS GROUP

This group contains the only wetland vegetation occurring in the Bull Run Mountains' interior valleys and stream bottoms. Habitats are saturated by groundwater discharging from adjacent toe slopes and are characterized by damp to wet soil conditions for most or part of the growing season. Small areas of shallow water commonly occur in springs, seepage rills, mucky depressions, and streamlets, but these habitats are never inundated by overland flooding. Hummock-and-hollow microtopography with braided streamlets is typical. Vegetation is a palustrine forest usually dominated by red maple (*Acer rubrum*) and containing an abundance of skunk-cabbage (*Symplocarpus foetidus*) in the herb layer. Species diversity is relatively high. This is a globally rare natural community, endemic to the Central Appalachians, that covers less than 40 hectares (100 acres) in the Bull Run Mountains. At present, the most serious threat to this group is posed by invasive non-native plants, particularly Japanese stilt grass (*Microstegium vimineum*), which is capable of growing well on the better drained hummocks.

Plate 3. Seepage swamp along the headwaters of Catharpin Creek and Jackson Hollow. Plot BULL012R, May28, 2014. Note the patch-dominance of the colonial, leafy forbs American false hellebore (*Veratrum viride*) and skunk-cabbage (*Symplocarpus foetidus*).

Plot BULL012P/R

2001 Species Richness: 65
2014 Species Richness: 53
2001 Density and Basal Area: 925 stems/ha; 30.2 m^2/ha
2014 Density and Basal Area: 900 stems/ha; 40.32 m^2/ha

The plot is situated in a linear band of forested seepage swamps that stretches for approximately one kilometer (0.6 mi.) along the south headwaters branch of Catharpin Creek and Jackson Hollow, west of Rt. 629. The original 2001 sample was representative of these swamps, which typically supported nearly continuous swards of skunk-cabbage (*Symplocarpus foetidus*) and a variety of ferns in the herb layer. Moderately high pH, Ca, and Mg levels and high Mn levels in soil samples suggested enrichment by groundwater inputs and/or base-rich alluvium from phyllite or metasiltstone. A narrow, elongate plot configuration (10 X 40 m) was used to avoid the inclusion of adjacent upland habitat. Data from the 2014 resampling indicates that the most significant change at this site since 2001 is an exponential increase in the cover of Japanese stilt grass (*Microstegium vimineum*) from <1% cover to >25% cover. At the same time, the overall species richness of the plot decreased from 65 taxa in 2001 to 53 taxa in 2014. Since most of the taxa that were not observed in the 2014 resample are herbaceous species that occurred at low cover in 2001, this decrease in diversity may be due to the suppressing effects of the invasive Japanese stilt grass. The total density of woody stems has decreased slightly but the total basal area has increased significantly, reflecting the growth of the trees over the past 13 years.

Plot BULL014P/R

2001 Species Richness: 78
2014 Species Richness: 85
2001 Density and Basal Area: 600 stems/ha; 21.7 m^2/ha
2014 Density and Basal Area: 525 stems/ha; 27.6 m^2/ha

This plot was located in an open, swampy forest at the headwaters of Little Bull Run north of Hopewell Gap. In 2001, large thickets of common greenbrier (*Smilax rotundifolia*) were interpreted as indicators of past disturbance. The vegetation, however, was fairly typical for the habitat, containing the characteristic suite of seepage-swamp species, including red maple (*Acer rubrum*), winterberry (*Ilex verticillata*), hairy highbush blueberry (*Vaccinium fuscatum*), skunk-cabbage (*Symplocarpus foetidus*), and cinnamon fern (*Osmundastrum cinnamomeum*). The northern and montane forb American false hellebore (*Veratrum viride*) was also notably abundant. An elongate plot configuration (10 X 40 m) was necessary to eliminate adjacent upland habitat from the sampling area. Although not recorded within the plot boundaries, Japanese stilt grass (*Microstegium vimineum*) was abundant nearby. The habitat and vegetation appear much the same in the resampled 2014 quadrat as in the original plot of 2001. Total species richness is slightly higher (85 taxa vs. 78 in 2001); total density of woody stems is slightly lower due to the loss of several shrubs; and total basal area is considerably higher due to the growth of the larger trees. However, the invasive Japanese stilt grass has moved in and now covers >10% of the plot, which does not bode well for the continued diversity of low-cover herbaceous species.

Plot BULL015P/R

2001 Species Richness: 53
2014 Species Richness: 52
2001 Density and Basal Area: 1500 stems/ha; 26.1 m^2/ha
2014 Density and Basal Area: 1300 stems/ha; 38.6 m^2/ha

This plot is positioned in a narrow, sloping tributary seep which emerges from the foot of a slope and flows for about 50 meters before emptying into the headwaters of Hungry Run. Despite an elongate configuration (10 X 40 m), a few square meters of adjacent upland habitat was unavoidable and

included within the plot boundary. In 2001, the vegetation was considered an outstanding example of a forested seepage swamp with exceptional woody diversity. Sixteen species were recorded in the shrub layer. An unusual feature of the herbaceous flora is the only known Piedmont occurrence of northern starflower (*Trientalis borealis*), a species characteristic of northern and high-elevation Appalachian forests. The habitat and vegetation of this plot have changed very little since 2001. Floristic composition and total species richness of the two samples are almost identical. The significantly larger basal area of the 2014 resample is due to a slight discrepancy in the boundary that included an additional large tuliptree (*Liriodendron tulipifera*). Woody species diversity continues to be outstanding and the unusual population of northern starflower noted in 2001 is vigorous and apparently even larger now.

Plot BULL065P/R

2001 Species Richness: 57
2014 Species Richness: 69
2001 Density and Basal Area: 1850 stems/ha; 26.0 m^2/ha
2014 Density and Basal Area: 1050 stems/ha; 31.3 m^2/ha

The habitat of this plot is a swampy stream bottom in a deep ravine at the west foot of High Acre Ridge. An elongate plot (10 X 40 m) was placed parallel to the stream in order to restrict sampling to the wetland habitat. Even so, the plot contains considerable microtopographic and floristic heterogeneity because of braided drainage, hummocks, and local lateral seepage. In 2001, herbaceous mesophytes such as New York fern (*Parathelypteris noveboracensis*) dominated the better-drained hummocks, while a variety of wetland species prevailed elsewhere. The wetland forbs skunk-cabbage (*Symplocarpus foetidus*) and American false hellebore (*Veratrum viride*) had mostly died back for the season on the late (August 10) sampling date. Noticeable deer grazing was recorded on five herbaceous species, including cinnamon fern (*Osmundastrum cinnamomeum*). Most of the differences between the 2014 resampled data and the original 2001 plot can probably be attributed to the earlier sampling date (June 6) of the former. More herbaceous species are present in the resampled plot, and others, particularly American false hellebore, have higher cover due to their seasonal growth cycles. All the larger trees of the original plot sample are still present and have grown considerably, but the shrubs smooth alder (*Alnus serrulata*) and witch-hazel (*Hamamelis virginiana*) have both declined in stem density. Two highly invasive non-native plants – Japanese stilt grass (*Microstegium vimineum*) and Asiatic bittersweet (*Celastrus orbiculatus*) - have become established at low cover, while a third – lesser celandine (*Ficaria verna*) - has invaded several areas not far to the east of the plot. The latter is well adapted to saturated habitats, is highly invasive via stolons and perennial tubers, and poses a major potential threat to this wetland. The deer grazing impacts noted in the 2001 sample were not seen in the 2014 resample.

Plot BULL068P/R

2001 Species Richness: 77
2014 Species Richness: 82
2001 Density and Basal Area: 700 stems/ha; 33.2 m^2/ha
2014 Density and Basal Area: 825 stems/ha; 36.1 m^2/ha

Numerous springs and seeps saturate this broad, headwaters stream bottom at the foot of the High Point Mountain. Although the habitat is littered with quartzite boulders and cobbles weathered from rocks of the mountain slope above, mean groundwater pH (6.74) from five samples suggests the influence of underlying base-rich metabasalt. In addition, overall species richness and the prominence of certain species such as white ash (*Fraxinus americana*), black ash (*Fraxinus nigra*), and drooping sedge (*Carex prasina*) in the 2001 plot sample suggest soils with relatively high base status. Although now reforested, much of the land adjacent to and just downslope from this seep appeared to have been cleared in the past. Discrepancies in the woody vegetation between the 2001 and 2014 samples suggest

that the boundaries reconstructed in 2014 do not exactly match those of the original plot. The resample appears to have captured a hummock area on the north edge of the plot containing a number of saplings of upland trees, especially bitternut hickory (*Carya cordiformis*) and American beech (*Fagus grandifolia*). Nevertheless, the large trees recorded in 2001 are all still present, and overall floristic composition and relative species abundances are similar in both samples. The overall data suggest that this habitat and its noteworthy swamp vegetation have not changed appreciably over the last thirteen years. The invasive Japanese stilt grass (*Microstegium vimineum*) is, however, likely more abundant on the better drained hummocks. Although its estimated cover (1-2%) was the same in both samples, the 2014 sampling was conducted in May, when this annual was just sprouted and very small, while the 2001 sampling was conducted in August, when the species reaches much larger size.

MESIC FORESTS GROUP

This group contains tall, well-formed forests of lower slopes, ravines, and stream bottoms. It includes several community types that occupy a range of moist, extremely acidic to base-rich soils. Tuliptree (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), northern red oak (*Quercus rubra*), white ash (*Fraxinus americana*) are typical trees. On the richer sites, pawpaw (*Asimina triloba*) and spicebush (*Lindera benzoin*) are abundant in the understory. Ferns are common in the herb layer. This vegetation covers large but discrete patches in suitable habitats, covering several hundred hectares in the Bull Run Mountains. Invasive non-native plants, excessive deer herbivory, and non-native pathogens such as dogwood anthracnose are all serious disturbances that have plagued mesic forests in recent decades.

Plate 4. Rich, mesophytic forest of tuliptree and northern red oak, in ravine at north end of High Point Mountain. Plot BULL059R, May 30, 2014.

Plot BULL007P/R

2001 Species Richness: 76
2012 Species Richness: 81
2001 Density and Basal Area: 1200 stems/ha; 47.2 m^2/ha
2012 Density and Basal Area: 1100 stems/ha; 38.7 m^2/ha

In 2001, this plot captured a fairly diverse mesophytic forest with a lush herb layer, growing on the lower slope of a moist ravine (Fern Hollow). Very tall, well-formed tuliptrees (*Liriodendron tulipifera*) dominated the overstory, while hickories (*Carya* spp.) dominated the understory, suggesting a long-term successional trend. Significant deer herbivory on herbaceous plants was noted. A deer exclosure was constructed around the quadrat by Eagle Scouts in 2012, a short time before the resampling was conducted. Conditions have changed considerably since 2001. Two blowdowns have created light gaps and tip-up mound soil disturbances that have led to the establishment of the non-native vines wineberry (*Rubus phoenocolasius*) and Asiatic bittersweet (*Celastrus orbiculatus*). However, it is remarkable that only three non-native plants occurred in the resampled plot, all at low cover (only one occurred in 2001). The most obvious change is in the herbaceous flora, which has lower overall cover and differs from the 2001 sample in the relative abundance of some species. In 2001, maidenhair fern (*Adiantum pedatum*) (25-50% cover), black cohosh (*Actaea racemosa*), and violet wood sorrel (*Oxalis violacea*) (both 10-25% cover) had the highest herbaceous cover. In 2012, these species had been reduced to 5-10%, 1-2%, and 0% (absent), while the unpalatable species hog-peanut (*Amphicarpaea bracteata*) (<1% in 2001) and southern lady fern (*Athyrium asplenioides*) (2-5% in 2001) had increased to 10-25% and 5-10% respectively. The only possible explanation for such pronounced changes is a dramatic increase in deer herbivory and selective grazing pressure, which has been evident over the entire northern Virginia region in the last decade.

Plot BULL017P/R

2001 Species Richness: 48
2014 Species Richness: 43
2001 Density and Basal Area: 1025 stems/ha; 51.7 m^2/ha
2014 Density and Basal Area: 900 stems/ha; 58.3 m^2/ha

The habitat of this plot, a gentle, lower slope in Jackson Hollow, was almost certainly cleared or heavily cut long ago, and subsequently reforested with an even-aged stand of shade-intolerant trees such as tuliptree (*Liriodendron tulipifera*), black oak (*Quercus velutina*), and scarlet oak (*Quercus coccinea*). In 2001, stand composition was in a transitional stage, with American beech (*Fagus grandifolia*) having become abundant in the understory and poised to assume future dominance. Little has changed since the 2001 sampling. The trees have grown larger and five herbaceous species that occurred in very low numbers in 2001 were not observed in 2014. The stand is continuing its slow but inexorable transition from a forest of tuliptree and oaks to one dominated by beech. Deer browse impacts remain heavy and problematic.

Plot BULL026P/R

2001 Species Richness: 30
2014 Species Richness: 19
2001 Density and Basal Area: 2625 stems/ha; 37.7 m^2/ha
2014 Density and Basal Area: 5350 stems/ha; 52.3 m^2/ha

The vegetation in this narrow, sheltered ravine bottom on the East Ridge is unique in the Bull Run Mountains. In 2001, the mixed tree layers contained the regionally uncommon species eastern white pine (*Pinus strobus*) and eastern hemlock (*Tsuga canadensis*), along with several hardwoods. Great rhododendron (*Rhododendron maximum*), which is rare everywhere in northern Virginia, dominated the

shrub layer in dense thickets. The few hemlocks in the stand were infested with the woolly adelgid pathogen and herbivory damage was noted on several shrubs and herbs. Both eastern hemlock trees that were present in the 2001 sample died prior to the 2014 resampling. Much of the rest of the tree composition remains the same, with strong growth that has increased the stand basal area considerably. The number of measureable (> 2.5 cm DBH) stems of great rhododendron has increased dramatically from 69 in 2001 to 169 in 2014. The tremendous growth of this species over the last 13 years has increased deep shading in the ravine bottom and possibly contributed to the reduction of species richness from 30 taxa to 19. However, some of the species not observed in 2014 were low-cover herbs and shrubs on which heavy deer browse damage was noted in 2001, leading to a suspicion that herbivory has also contributed to this decline.

Plot BULL036P/R

2001 Species Richness: 64
2014 Species Richness: 76
2001 Density and Basal Area: 1125 stems/ha; 42/5 m^2/ha
2014 Density and Basal Area: 1225 stems/ha; 45.2 m^2/ha

This plot is located in an excellent example of mesophytic hardwood forest occurring on a stream bottom in Jackson Hollow with relatively nutrient-poor soils. In 2001, the mixed overstory contained mature American beech (*Fagus grandifolia*), tuliptree (*Liriodendron tulipifera*), northern red oak (*Quercus rubra*), red maple (*Acer rubrum*), and American basswood (*Tilia americana* var. *americana*), which is unknown elsewhere in the Bull Run Mountains. American hornbeam (*Carpinus caroliniana*) and witch-hazel (*Hamamelis virginiana*) dominated the understory. The herb layer was patchy but fairly diverse, despite noticeable damage from deer-grazing on several species. On the May 29, 2014 resampling date, there was ample evidence of recent flash flooding in the stream bottom following heavy rains. The bottom was scoured of leaf litter, herbaceous plants were knocked over, and piles of flood-deposited woody debris were scattered through the area. Other than these rare and temporary flood impacts, the habitat and vegetation of this plot were very similar to those documented here thirteen years earlier. Floristic composition, woody stem density, and total basal area are all very close between the two samples. Species richness of the 2014 sample is 12 taxa higher, but this is at least partly accounted for by a May sampling date during a wet spring (vs. July sampling date during a dry year). Remarkably, this is one of the few sites in which Japanese stilt grass (*Microstegium vimineum*) has not increased in cover since 2001 (it was <1% cover in both samples).

Plot BULL059R/P

2001 Species Richness: 38
2014 Species Richness: 41
2001 Density and Basal Area: 275 stems/ha; 52.0 m^2/ha
2014 Density and Basal Area: 425 stems/ha; 61.4 m^2/ha

This beautiful, rich mesophytic forest occupies a sheltered, north-facing, cove-like ravine at the north end of the High Point ridge. Soils are apparently deep, dark, and loamy, with relatively high calcium, magnesium, and total base saturation. The stand features an overstory of large tuliptree (*Liriodendron tulipifera*) and northern red oak (*Quercus rubra*), a very open understory, and a lush herb layer of nutrient-demanding ferns and forbs. Since 2001, the large canopy trees have continued to grow at an impressive rate, and measureable stems of several shrubs and tree saplings have increased. The herb-layer dominants are the same as in 2001, but Japanese stilt grass (*Microstegium vimineum*, absent in the earlier sample) now constitutes >10% cover in this layer. It remains to be seen whether this invasive grass can outcompete the much larger and coarser herbaceous dominants here and continue to spread. Long-bristled smartweed (*Persicaria longiseta*), the only non-native plant present in 2001, has increased

in cover from <1% to >2%. Three other problematic invasives have also become established: wineberry (*Rubus phoenicolasius*, >2% cover), garlic-mustard (*Alliaria petiolata*, <1% cover), and Asiatic bittersweet (*Celastrus orbiculatus*, <1% cover). All three have the potential for achieving patch-dominance in this type of forest vegetation.

OAK – HICKORY AND MIXED OAK FORESTS GROUP

The forests of this group occupy sites of intermediate moisture conditions, i.e., submesic to subxeric slopes with relatively deep soils. Oaks, including white oak (*Quercus alba*), chestnut oak (*Quercus montana*), northern red oak (*Quercus rubra*), and black oak (*Quercus velutina*), are prevalent in the overstory; hickories (*Carya* spp.) are also common but sometimes restricted to the understory. Shrub and herbaceous vegetation is often diverse, and lacks the strong dominance of ericaceous (heath) species such as mountain-laurel (*Kalmia latifolia*) and blueberries (*Vaccinium* spp.) that characterizes the oak / heath forests (see below). Oak-hickory and mixed oak forests cover hundreds of hectares in the Bull Run Mountains, especially (though by no means exclusively) on the east-facing dip slopes of the ridges. In recent decades the forests of this group have been increasingly degraded by a number of disturbances, including extensive mortality of flowering dogwood from the dogwood anthracnose fungus; invasion of habitats by Japanese stilt grass (*Microstegium vimineum*) and other non-native weeds; and over-grazing by white-tailed deer, which has nearly eliminated formerly abundant forbs and shifted herbaceous dominance to unpalatable graminoids. Moreover, many of these forests are exhibiting a decline of oaks, with younger tree recruitment consisting mostly of hickories and/or red maple (*Acer rubrum*). The exotic pathogen gypsy moth (*Lymantria dispar*) was problematic in these forests from the late 1980's to about 2002, but outbreaks have been small and infrequent since then.

Plate 5. Typical oak-hickory forest on upper east slope of High Point Mountain above the headwaters of Catletts Branch. Plot BULL044R, May 30, 2014.

Plot BULL016P/R

2001 Species Richness: 53
2014 Species Richness: 69
2001 Density and Basal Area: 875 stems/ha; 66.1 m^2/ha
2014 Density and Basal Area: 625 stems/ha; 41.2 m^2/ha

Located north of Hopewell Gap on the Middle Ridge, the original plot documented a submesic, middle-slope oak-hickory forest of medium-sized to large trees. Some dieback from the fungal pathogen dogwood anthracnose was noted on flowering dogwood (*Cornus florida*), although it was still one of the dominant understory trees. Heavy herbivory by white-tailed deer had greatly reduced the stature of many herbs. Since 2001, four overstory trees in this plot have died or blown down, including the 90 cm DBH chestnut oak (*Quercus montana*) tag tree. In addition, seven flowering dogwood trees have succumbed to anthracnose. These disturbances have resulted in a significant reduction of total woody stem density and basal area, as well as large gaps that together constitute a little more than half the canopy of the plot. The large increase in light reaching the forest floor, coupled with soil disturbances from falling trees, has led to an increase of overall species richness from 53 taxa in 2001 to 69 taxa in 2014 (the majority of newcomers being low-cover native forest herbs), as well as a notable increase of cover among deer-resistant graminoids, particularly sedges (*Carex* spp.). Unfortunately, the species which have increased far more than others are the non-native weeds Japanese stilt grass (*Microstegium vimineum*), which was absent in 2001 and now covers >25% of the plot; and wineberry (*Rubus phoenicolasius*), which increased from <1% cover in 2001 to >10% cover in 2014. If the cover of these invasive species continues to increase, a future reduction in native herb diversity will be likely. Oak recruitment remains low to non-existent in and around the plot, with red maple (*Acer rubrum*) and American beech (*Fagus grandifolia*) showing marked increases in the understory.

Plot BULL018P/R

2001 Species Richness: 33
2014 Species Richness: 25
2001 Density and Basal Area: 1525 stems/ha; 30.7 m^2/ha
2014 Density and Basal Area: 1300 stems/ha; 42.4 m^2/ha

The forest overstory on this lower slope near the headwaters of Catletts Branch is dominated by chestnut oak (*Quercus montana*), with red maple (*Acer rubrum*) dominant in the understory, and patchy shrubs and herbs. An apparent discrepancy between the boundaries of the 2001 and 2014 samples resulted in some differences in tree composition that make it difficult to compare changes in density and basal area. However, there do not appear to be any disturbance-related changes in the major woody vegetation, and the trees sampled in 2001 have grown considerably larger. Very heavy deer herbivory has clearly reduced the low shrub and herb cover in the plot. The many shrub-sized chestnut oaks (*Quercus montana*) noted in 2001 have been eliminated, and the cover of early lowbush blueberry (*Vaccinium pallidum*) and deerberry (*Vaccinium stamineum*) have been reduced from >5% each in 2001 to <2% and <1%, respectively in the more recent sample. In addition, several herbaceous species and trees that occurred as seedlings have been extirpated, contributing to an overall reduction of species richness from 33 to 25 taxa.

Plot BULL021P/R

2001 Species Richness: 63
2014 Species Richness: 72
2001 Density and Basal Area: 1800 stems/ha; 24.6 m^2/ha
2014 Density and Basal Area: 1900 stems/ha; 32.2 m^2/ha

In 2001, this plot captured a somewhat scrubby oak-hickory forest occupying a dry, rocky, east-facing slope along the former Hickory Trail on the east slope of High Point. The stand had relatively high species richness, several large oaks, and abundant hickories (*Carya* spp.) in the understory. Gypsy moth damage and heavy deer herbivory were notable disturbances. The habitat and vegetation of this diverse forest have not changed significantly since 2001. Two of the larger trees had parts of their tops blown out, but are still very much alive. The total basal area has increased slightly due the growth of trees, and total species richness has increased by nine taxa. Several potentially invasive non-native plants are present, including garlic mustard (*Alliaria petiolata*), but still occur only at low (<1%) cover.

Plot BULL030P/R

2001 Species Richness: 44
2014 Species Richness: 50
2001 Density and Basal Area: 1025 stems/ha; 32.1 m^2/ha
2014 Density and Basal Area: 1175 stems/ha; 24.0 m^2/ha

The 2001 plot documented a mixed oak and hickory forest with a rather sparse but fairly diverse herb layer, representative of stands that prevailed over the eastern flank of the Bull Run Mountain East Ridge north of Hopewell Gap. The openly wooded slope is very accessible to white-tailed deer, whose grazing contributed to the low density and cover of herbs and shrubs. Since the original 2001 sampling, three dominant oaks have died, one of them creating a large canopy gap in the southwestern part of the plot. Unlike many stands on Bull Run Mountain where oaks are decadent, this one nearly lacks red maple (*Acer rubrum*) in the understory and most of the younger tree recruitment consists of hickories (*Carya ovalis* and *Carya tomentosa*). Very heavy levels of deer herbivory continue to suppress the cover and vigor of herbaceous plants in this plot.

Plot BULL031P/R

2001 Species Richness: 50
2014 Species Richness: 59
2001 Density and Basal Area: 825 stems/ha; 34.2 m^2/ha
2014 Density and Basal Area: 700 stems/ha; 33.1 m^2/ha

In 2001, this plot was similar to plot BULL030, which is located about 0.50 km to the south on the same eastern flank of the Bull Run Mountain East Ridge. However, it occupied a more convex and seemingly drier slope with greater cover of mineral soil exposed by sheet-erosion. The herb layer was relatively dense (ca. 50% cover) and dominated by white snakeroot (*Ageratina altissima* var. *altissima*) and several grasses and sedges that are unpalatable to deer. Since 2001, the large northern red oak (*Quercus rubra*) tag tree has blown down, creating a large canopy gap on the western side of the plot. Additionally, the areas of bare mineral soil present in 2001 have become covered by humus and duff. Otherwise, conditions remain similar, with chestnut oak (*Quercus montana*) dominating the overstory, hickories (*Carya* spp.) dominating the understory, and the herb flora exhibiting only minor shifts in cover and relative species abundances. The potentially invasive non-native garlic mustard (*Alliaria petiolata*) has become established in very small numbers. High levels of deer herbivory continue to shape the composition and stature of the herb layer.

Plot BULL037P/R

2001 Species Richness: 38
2014 Species Richness: 47
2001 Density and Basal Area: 825 stems/ha; 59.4 m^2/ha
2014 Density and Basal Area: 725 stems/ha; 59.9 m^2/ha

This plot documented a small patch of old-age forest occupying a rugged boulderfield on a north-facing slope of Jackson Hollow. Soils were very limited and largely interstitial; the herbaceous flora was dominated by lithophytic ferns, particularly rock polypody (*Polypodium virginianum*) and marginal wood fern (*Dryopteris marginalis*), capable of growing in crevices and organic mats. More demanding forbs such as black cohosh (*Actaea racemosa*) inhabited a few flat boulders and ledges where loamy colluvium had been deposited. Dominant individuals of chestnut oak (*Quercus montana*) and tuliptree (*Liriodendron tulipifera*) were truly impressive, with some approaching 1.0 m DBH. With the exception of one wind-thrown chestnut oak and another that died (still standing), all the larger trees recorded in 2001 were still present in the 2014 resample, and total stand basal area was almost identical to that of the earlier sample. The anthracnose fungus has claimed two of the four flowering dogwoods (*Cornus florida*) recorded in 2001. There have been mostly only minor changes to the low shrub and herbaceous flora, but a noticeable increase in the cover of wineberry (*Rubus phoen*icolasius) from <2% to >5% is problematic given the invasive tendencies of this Asiatic shrub.

Plate 6. This stand in Jackson Hollow occupies an unusual, boulderfield habitat with old-age trees. Plot BULL037R, June 10, 2014.

Plot BULL038P/R

2001 Species Richness: 62
2014 Species Richness: 73
2001 Density and Basal Area: 1175 stems/ha; 37.4 m^2/ha
2014 Density and Basal Area: 1050 stems/ha; 28.3 m^2/ha

The plot is located on the middle, west-facing slope of the East Ridge south of Hopewell Gap. In 2001, white oak (*Quercus alba*) and tulip-poplar (*Liriodendron tulipifera*) co-dominated this medium-age stand, which also contained some pignut hickory (*Carya glabra*), chestnut oak (*Quercus montana*), and

northern red oak (*Quercus rubra*), along with red maple (*Acer rubrum*) in the understory. Flowering dogwood (*Cornus florida*), formerly a dominant small tree/shrub, had nearly been eliminated by the introduced fungal pathogen dogwood anthracnose. The herb flora was rather diverse but had surprisingly low and patchy cover, apparently the result of repeated top-grazing by white-tailed deer. Stand composition has continued to change since 2001, as what little oak recruitment was present has died off, the dominant red maple understory has continued to grow in size and importance, and only a single dogwood has survived the anthracnose. Although white oak is still the most dominant overstory tree in the stand, the large 73 cm DBH tag tree from the 2001 plot has blown down, littering part of the area with coarse woody debris and contributing to a significant decrease in stand basal area. Two small tuliptrees have also died. The herbaceous flora is more or less comparable to that in the 2001 sample, with only some minor species turnover and fluctuations in abundance. However, Japanese stilt grass (*Microstegium vimineum*), which was absent in 2001, has become established here and can be expected to increase rapidly as it has in many other oak-hickory forests of the area.

Plot BULL043P/R

2001 Species Richness: 35
2014 Species Richness: 42
2001 Density and Basal Area: 1325 stems/ha; 77.6 m^2/ha
2014 Density and Basal Area: 900 stems/ha; 59.4 m^2/ha

This plot is located in an old-age forest stand that stretches for approximately 0.5 km along the extremely bouldery foot of the High Point Mountain cliffs. The forest is an uneven-age stand that apparently escaped cutting because of limited accessibility and the poor growth form of trees. Many individuals of chestnut oak (*Quercus montana*), northern red oak (*Quercus rubra*), and tuliptree (*Liriodendron tulipifera*) from 90 to 108 cm DBH occur in the area; although almost all of these massive specimens are hollow, extrapolation of partial increment cores indicate ages > 200 years (and possibly much older) for chestnut oak. The most significant change in this plot since 2001 has been the death of the impressive (108 cm DBH), old-growth chestnut oak tag tree at the south end of the plot. The loss of this single tree has resulted in a very significant reduction of stand basal area. All the other large and medium-sized trees are still present. This stand is a bit unusual in having about ten chestnut oaks in the subcanopy, and a relatively low density of red maple (*Acer rubrum*) recruitment. The herb layer is still dominated by part of a clone of wild sarsaparilla (*Aralia nudicaulis*) that covers at least several hectares on the upper west and north slopes of High Point Mountain; the cover of this species in the plot has increased from 25-50% in 2001 to 50-75% in 2014. Japanese stilt grass (*Microstegium vimineum*) was newly recorded in 2014, albeit in very low numbers. It remains to be seen whether this bouldery and densely vegetated habitat will be suitable for it to persist and spread.

Plot BULL044P/R

2001 Species Richness: 70
2014 Species Richness: 63
2001 Density and Basal Area: 750 stems/ha; 30.5 m^2/ha
2014 Density and Basal Area: 625 stems/ha; 31.3 m^2/ha

This second-growth oak-hickory forest is associated with soils weathered from the flaggy quartzite / muscovite schist / phyllite geological suite, which underlies much of the eastern flank of High Point Mountain. In 2001, red hickory (*Carya ovalis*) shared overstory dominance with several oaks (*Quercus* spp.) and tuliptree (*Liriodendron tulipifera*), while mockernut hickory (*Carya tomentosa*) dominated the understory. *Cornus florida,* formerly a dominant small tree/shrub, had been recently devastated by the introduced fungal pathogen dogwood anthracnose. Despite heavy deer herbivory, the original plot sample had impressive species-richness, in large part because of a patchy but diverse cover of

herbaceous species. In the 2014 resample, the woody vegetation is much the same as in 2001, except that the trees are larger and a large black oak (*Quercus velutina*) of the earlier sample has died. Hickories continue to dominate of the stand, with low recruitment of oak and red maple (Acer rubrum). Heavy deer grazing of the herb layer continues; black cohosh (*Actaea racemosa*) has been particularly hard hit, being reduced from >5% cover in 2001 to <1% cover in 2014. Overall species richness of the plot has also declined slightly. Remarkably, Japanese stilt grass (*Microstegium vimineum*), which covered <1% in 2001, has not increased measurably over the past thirteen years. However, several new non-native plants have appeared; among these, wineberry (*Rubus phoenicolasius*) is particularly problematic, covering >5% of the plot.

Plate 7. Open, white oak-dominated forest with hickory subcanopy and patchy, graminoid-dominated herb layer on west-facing slope above Catletts Branch. Plot BULL052R, June 16, 2014.

Plot BULL052P/R

2001 Species Richness: 54
2014 Species Richness: 65
2001 Density and Basal Area: 1550 stems/ha; 38.4 m^2/ha
2014 Density and Basal Area: 2225 stems/ha; 48.0 m^2/ha

In 2001, this west-facing slope above Catletts Branch had considerable exposed, silty mineral soil and supported a mixed oak-hickory forest with many low-cover herbaceous xerophytes. White oak (*Quercus alba*) was the overstory dominant, with other oaks and white ash (*Fraxinus americana*) as scattered associates. Hickories (*Carya* spp.) were common in the understory and black haw (*Viburnum prunifolium*) was dominant in the shrub layer. In overall character, this plot is currently much the same as in 2001 - a dryish, white oak-dominated forest with black haw dominant in the shrub layer and a

patchy herb layer rich in grasses and sedges. The dominant oaks have grown considerably and the density of measureable black haw stems has increased by nearly 100%. Most of the higher-cover herbs in 2001 were judged to have similar cover in 2014. However, an erosion gully at the north edge of the plot has deepened over the years, and Japanese stilt grass (*Microstegium vimineum*) has become established both there and in the old road bed above the plot. Overall species richness in the sample increased from 54 to 65 species, and it was not merely the result of new species becoming established. Twelve herb and shrub species recorded in 2001 were not found in the resampling, while 23 new herbs and shrubs were added. The reasons for this fairly significant species turnover are not clear. Deer herbivory does not appear to be a strong influence on ground-level composition here; or if it is, herbivory levels have not changed much since 2001. Some of the turnover could be due to differences in sampling times/conditions (July 26 in 2001, during a very dry summer vs. June 16, 2014, after a much wetter spring).

Plot BULL058P/R

2001 Species Richness: 65
2014 Species Richness: 74
2001 Density and Basal Area: 400 stems/ha; 32.4 m^2/ha
2014 Density and Basal Area: 300 stems/ha; 33.8 m^2/ha

This plot occupies a north-facing upper slope at the northern terminus of High Point Mountain, where this ridge begins to drop off into a deep ravine system. In 2001, the forest here had a distinctive structure and composition which featured a closed canopy of oaks (*Quercus* spp.), red hickory (*Carya ovalis*), and tuliptree (*Liriodendron tulipifera*); very sparse subcanopy and shrub layers; and a dense herb layer dominated by part of a huge clone of wild sarsaparilla (*Aralia nudicaulis*). In 2014, the general appearance of the plot was much the same as in 2001, but several small trees and one large northern red oak (*Quercus rubra*) had died. The cover of wild sarsaparilla decreased somewhat, while 19 herbs and woody seedlings recorded in 2001 were not found, and 28 new species were added. The reason for this species turnover is not clear. Wineberry (*Rubus phoenicolasius*), while occurring at low cover, has become established in the plot, and Japanese stilt grass (*Microstegium vimineum*) is established nearby.

Plot BULL067P/R

2001 Species Richness: 49
2014 Species Richness: 50
2001 Density and Basal Area: 1725 stems/ha; 32.6 m^2/ha
2014 Density and Basal Area: 1250 stems/ha; 34.5 m^2/ha

The original plot detailed a mixed, second-growth stand of chestnut oak (*Quercus montana*), northern red oak (*Quercus rubra*), tuliptree (*Liriodendron tulipifera*), and pignut hickory (*Carya glabra*) located in a ravine at the east foot of High Acre Ridge. This was also one of a very few sites in the Bull Run Mountains where sweet birch (*Betula lenta*) occurred. The dominance of large specimens of wild azalea (*Rhododendron periclymenoides*) in the shrub layer was also unusual among plot samples from the area. Since 2001, three of the six chestnut oaks in this plot have died, and this species appears to be on the decline. On the other hand, the larger northern red oak, tuliptree, and sweet birch trees in the plot have grown considerably. Shrub and herb composition has changed markedly in the last thirteen years. Stem density of wild azalea, the dominant shrub in 2001, has declined by almost 50%, and deer have browsed this species heavily up to about two meters in height. While not a dominant shrub, mountain-laurel (*Kalmia latifolia*) has also declined and now exhibits the branch dieback that has been observed widely in the Bull Run Mountain area. Early lowbush blueberry (*Vaccinium pallidum*) has been reduced in stature and cover since 2001 by heavy browsing, and deerberry (*Vaccinium stamineum*) (1-2% cover in 2001) has been extirpated. The herb layer has been affected by deer browse, as well as changes in

the physical environment, and has experienced considerable species turnover. In 2001, 25% of the surface substrate was exposed mineral soil, all of which had become covered by a mantle of duff and leaf litter by 2014. Fifteen herb/woody seedling species present in 2001were not present in 2014, while fifteen others were newly recorded; 22 herb/woody seedling species occurred in both samples.

Plot BULL069P/R

2001 Species Richness: 72
2014 Species Richness: 78
2001 Density and Basal Area: 1000 stems/ha; 52.3 m^2/ha
2014 Density and Basal Area: 1000 stems/ha; 42.4 m^2/ha

The vegetation captured in the original plot, located on the High Point west slope, was a rather dry forest with a mixed overstory of white oak (*Quercus alba*), chestnut oak (*Quercus montana*), northern red oak (*Quercus rubra*), black oak (*Quercus velutina*), and some tuliptree (*Liriodendron tulipifera*). Hickories (*Carya* spp.) and young oaks dominated the understory. This sample had notably high species richness for such a dry and somewhat infertile site. The herb layer, though very diverse, had been heavily impacted by deer grazing, with heavy herbivory noted on at least ten species. In 2014, the stand remained unusual in lacking red maple (*Acer rubrum*) in the understory. Most of the younger tree recruitment is that of hickories, which have increased significantly in size and density since 2001. Two dominant overstory oaks (northern red and chestnut) of the 2001 sample have blown down, creating large canopy gaps. The remainder of the 2001 canopy – one tuliptree, two white oaks, and two black oaks – are still present and have grown considerably larger over the past thirteen years. Typical of this community type in the Bull Run Mountains, there has been considerable species turnover since 2001, particularly of low-cover herbaceous species. While 58 of the original species are still extant, 14 others were not found in 2014, and 20 new species were added. Among the latter were garlic mustard (*Alliaria petiolata*) and wineberry (*Rubus phoenicolasius*), both potentially highly invasive. Unfortunately, the invasive Japanese stilt grass (*Microstegium vimineum*), which had <1% cover in 2001, had 5 to 10% cover in the 2014 resample.

Plot BULL071P/R

2001 Species Richness: 57
2012 Species Richness: 68
2001 Density and Basal Area: 775 stems/ha; 25.6 m^2/ha
2012 Density and Basal Area: 750 stems/ha; 21.1 m^2/ha

Located on the upper east slope of the High Point ridge, this plot had an intact canopy in 2001 dominated by chestnut oak (*Quercus montana*) and mockernut hickory (*Carya tomentosa*), along with a diverse array of herbaceous plants supported by soils with relatively high base status. Significant herbivory was noted in 2001, and a deer exclosure was constructed around the quadrat by Eagle Scouts a short time before the plot was resampled in 2012. Conditions have changed considerably since 2001. A large windthrow and the death of another overstory tree (still standing) have created light gaps on the southeastern and southern sides of the plot. Some small saplings were also cut and minor trampling occurred during construction of the exclosure. The most obvious change is in the herbaceous flora, which in 2001 was dominated (10-25% cover) by black cohosh (*Actaea racemosa*). In 2012, this species had been reduced to <1% cover by heavy deer herbivory, and two unpalatable forest graminoids (*Dichanthelium boscii*, *Carex pensylvanica*) had greatly increased to take its place. Throughout the plot, low-cover forbs were reduced to small vegetative individuals of low vigor from repeated top-grazing. In addition, five weedy non-native plants that were not present in 2001 had appeared. At this point, all five occur at very low cover, but at least two – garlic mustard (*Alliaria petiolata*) and Japanese stilt grass (*Microstegium vimineum*) – have the potential to become invasive and cover large areas.

OAK / HEATH FORESTS GROUP

Oak/heath forests occupy dry, infertile, often rocky sites on slopes and ridge crests throughout the Bull Run Mountains. They are characterized by the dominance of oaks in the overstory, the dominance of ericaceous (heath-family) shrubs in the understory, very sparse cover of true herbs, and overall low floristic richness. Chestnut oak (*Quercus montana*) is the most characteristic tree, but scarlet oak (*Quercus coccinea*) and other oaks, as well as various pines, can be important in some stands. Shrub cover often exceeds 50% of a given area and varies from dense tangles of mountain-laurel (*Kalmia latifolia*) to low colonies of the deciduous heaths black huckleberry (*Gaylussacia baccata*), early lowbush blueberry (*Vaccinium pallidum*), and deerberry (*Vaccinium stamineum*). Oak/heath forests are estimated to cover > 1000 hectares (~ 3000 acres) in the Bull Run Mountains and form the matrix of the community patch-mosaic in this area. Their dry habitats, along with thick, poorly decomposed duff cover and high biomass of inflammable shrubs combine to make these forests highly susceptible to fire. Abundant evidence of past fires (i.e., tree scars, charcoal in soil) was found in many of the plots and was also noted by Allard and Leonard (1943). Due to a widespread effort to suppress wildfires starting in the mid-20th century, fire has been largely absent from the Bull Run Mountains for many decades. As a result, the composition of the area's oak/heath forests is now exhibiting a marked decline or even complete absence of oak recruitment, along with the abundant invasion of forest understories by mesophytic fire intolerant trees such as red maple (*Acer rubrum*) and American beech (*Fagus grandifolia*). The heath shrubs, which respond vigorously to periodic top-kill by fire, now often appear decadent with low vigor; and a dieback of mountain-laurel, the cause of which is currently unknown, has been observed in many places recently. Because these forests occupy poor, drought-prone sites, invasive weeds are rarely found in them, but deer browse can sometimes be severe on the low deciduous heaths. The exotic pathogen gypsy moth (*Lymantria dispar*) was problematic in the area's oak/heath forests from the late 1980's to about 2002, but outbreaks have been small and infrequent since then.

Plot BULL019P/R

2001 Species Richness: 28
2014 Species Richness: 22
2001 Density and Basal Area: 1375 stems/ha; 35.7 m^2/ha
2014 Density and Basal Area: 1500 stems/ha; 43.2 m^2/ha

Located near the headwaters of Catletts Branch, the habitat of this plot is a gentle lower slope with very infertile soils and a history of cutting and fire. In 2001, chestnut oak (*Quercus montana*), scarlet oak (*Quercus coccinea*), and black oak (*Quercus velutina*) co-dominated the overstory, with red maple (*Acer rubrum*) and black gum (*Nyssa sylvatica*) abundant in the understory. Deciduous ericads – including several blueberries (*Vaccinium* spp.) and black huckleberry (*Gaylussacia baccata*) – formed locally dense shrub colonies. Minor damage to oak foliage by gypsy moths was noted. There have been few noteworthy changes to this stand since 2001. All the trees sampled in 2001 are still present, albeit slightly larger. Five herbaceous species that occurred at very low cover in 2001 were not documented in 2014, and the stature and cover of blueberries have been considerably reduced, all likely due to high levels of deer herbivory in the area.

Plate 8. Rocky chestnut oak / mountain-laurel forest on the upper slope of the Middle Ridge north of Hopewell Gap. Similar forests are estimated to cover > 1000 hectares (3000 acres) in the Bull Run Mountains. Near plot BULL034R, Aug. 7, 2014.

Plot BULL020P/R

2001 Species Richness: 21
2014 Species Richness: 20
2001 Density and Basal Area: 1325 stems/ha; 37.7 m^2/ha
2014 Density and Basal Area: 1075 stems/ha; 39.5 m^2/ha

In 2001, this steep, dry, infertile slope near Thoroughfare Gap supported a medium-age forest dominated by stump-sprouted chestnut oaks (*Quercus montana*), with some black oak (*Quercus velutina*) also present. Herbaceous species were very sparse, with most of the herb-layer cover is contributed by low, ericaceous shrubs. Based on first appearances, this plot seemed little changed in 2014. However, closer inspection revealed several differences. One of the large black oak trees had died, along with all of the several mountain-laurel (*Kalmia latifolia*) shrubs. Small stems of sassafras (*Sassafras albidum*) and wild azalea (*Rhododendron periclymenoides*) measured in 2001 had also died, and the cover of black huckleberry (*Gaylussacia baccata*) and early lowbush blueberry (*Vaccinium pallidum*) had decreased from >5% and >10% to <2% and <5% respectively. However, the overall woody basal area and floristic composition is very close between the two samples. The habitat of this plot is quite xeric, and periodic drought stress may contribute to fluctuations in species abundances. Heavy deer browse is also a likely contributor to the reduction of deciduous ericads.

Plot BULL023P/R

2001 Species Richness: 29
2014 Species Richness: 25
2001 Density and Basal Area: 925 stems/ha; 38.0 m^2/ha
2014 Density and Basal Area: 875 stems/ha; 24.2 m^2/ha

In 2001, this plot documented a nearly closed canopy forest co-dominated by chestnut oak (*Quercus montana*) and scarlet oak (*Quercus coccinea*), with black huckleberry (*Gaylussacia baccata*) patch-dominant in a low deciduous shrub layer. Dogwood anthracnose, deer herbivory, and minor gypsy moth defoliation were noted in the vicinity. This plot has changed dramatically since 2001 because of a recent, localized wind event that greatly impacted the forest. Four large scarlet oaks, two chestnut oaks, and one white oak were blown down, causing several tip-up mounds and littering the area with coarse woody debris. The remaining tree canopy has been reduced to only about 35% cover. Much of the rest of the current vegetation is comparable to that present in 2001. The site is very dry, and insufficient time has passed to determine which species will dominate the regeneration. The plot is located near the Ridge Trail on the east slope High Point Mountain.

Plot BULL027P/R

2001 Species Richness: 17
2014 Species Richness: 24
2001 Density and Basal Area: 900 stems/ha; 41.9 m^2/ha
2014 Density and Basal Area: 875 stems/ha; 48.4 m^2/ha

This plot is situated on a slightly convex, upper slope on the north side of a saddle on the East Ridge, south of Hopewell Gap. In 2001, the vegetation was a fairly mature chestnut oak (*Quercus montana*)-dominated forest with typically low species richness but a lower density of ericaceous shrubs than many similar stands. This vegetation and its slightly sheltered habitat contrasted sharply with the stunted, oligotrophic pine / heath forest occurring on the crest and south side of the ridge (see plot BULL025P/R). While all the larger trees sampled in 2001 are still present, many saplings and small trees of the original plot have died. Additionally, many stems of mountain-laurel (*Kalmia latifolia*) have died back, and this species has been reduced from >10% cover in 2001 to <5% cover in 2014. A comparable decline of early lowbush blueberry (*Vaccinium pallidum*) was also recorded. Drought stress, high levels of deer browse, and/or lack of fire are possible contributors to these declines. An increase in plot species richness from 17 to 24 taxa is not significant since the added species are all represented by just one or very few seedlings.

Plot BULL034P/R

2001 Species Richness: 29
2014 Species Richness: 50
2001 Density and Basal Area: 2825 stems/ha; 41.6 m^2/ha
2014 Density and Basal Area: 2575 stems/ha; 43.0 m^2/ha

This plot is located just below the summit of the Middle Ridge, south of Hopewell Gap. During the original sampling, many stumps of American chestnut (*Castanea dentata*, probably cut in the 1920's) were found, indicating that this was once a mixed forest of chestnut and chestnut oak (*Quercus montana*). In 2001, the stand was dominated by chestnut oak with scattered tuliptree (*Liriodendron tulipifera*) and northern red oak (*Quercus rubra*), a dense sub-canopy of red maple (*Acer rubrum*), and a very dense shrub layer dominated by mountain-laurel (*Kalmia latifolia*). This plot has suffered multiple disturbances and undergone significant compositional changes since the 2001 sampling. A large northern red oak and several smaller chestnut oaks were wind-thrown, resulting in a very open (~35%) canopy with several gaps. Several understory black gums (*Nyssa sylvatica*) died, reducing the cover of

that species from >10% in 2001 to <2%. Some dieback of mountain-laurel branches was noted, even though the density of measureable stems increased slightly. Early lowbush blueberry (*Vaccinium pallidum*), which covered >5% of the plot in 2001, now covers <1%, likely due to heavy deer browse. Nine of the original 29 species recorded in 2001 were not found in 2014. However, 30 new species (not recorded in 2001) were documented in the 2014 resampling, including small pawpaw (*Asimina triloba*), many low-cover native forest herbs, and the potentially invasive non-native plants Japanese stilt grass (*Microstegium vimineum*), tree-of-heaven (*Ailanthus altissima*), and Asiatic bittersweet (*Celastrus orbiculatus*), contributing to a total species richness of 50 taxa. This is by one of the largest instances of species turnover recorded among the permanent Bull Run Mountain plots resampled in 2014. The fact that the stand is essentially an oak/heath forest, normally a species-poor vegetation type, makes this situation most unusual and worthy of close scrutiny in the future.

Plot BULL047P/R

2001 Species Richness: 22
2014 Species Richness: 19
2001 Density and Basal Area: 1650 stems/ha; 33.8 m^2/ha
2014 Density and Basal Area: 1575 stems/ha; 43.3 m^2/ha

In 2001, this plot was representative of second-growth chestnut oak (*Quercus montana*)- and mountain-laurel (*Kalmia latifolia*)-dominated forests that cover hundreds of acres on infertile Bull Run Mountain sideslopes. In spite of thick, root-rich duff and humus and dense understory competition, there was considerable recruitment of young chestnut oak (along with red maple and black gum) at this site, suggesting that this oak might maintain its dominant position into the future. Since 2001, however, the smaller chestnut oaks on this site have either attained a position in the canopy or died off. An even more significant change in this plot over the past 13 years is the extensive dieback of mountain-laurel branches that has reduced the cover of this shrub by about half (from ~35% in 2001 to ~15% in 2014. The stand continues to be strongly dominated by chestnut oak in the overstory and red maple and black gum in the understory. The concentration of chestnut oak in the overstory, and the dominance of red maple and other mesophytes such as American beech (*Fagus grandifolia*) in the understory, is an artifact of fire exclusion that does not bode well for the long-term viability of oaks on this dry ridge flanking Jackson Hollow.

Plot BULL049P/R

2001 Species Richness: 22
2014 Species Richness: 19
2001 Density and Basal Area: 1225 stems/ha; 38.1 m^2/ha
2014 Density and Basal Area: 1575 stems/ha; 41.9 m^2/ha

Large, mature specimens of white oak (*Quercus alba*), chestnut oak (*Quercus montana*), and American beech (*Fagus grandifolia*) were scattered on this steep, south-facing slope along Catletts Branch in 2001. Old stumps indicated that American chestnut (*Castanea dentata*) was also frequent here. Mountain-laurel (*Kalmia latifolia*) formed moderately dense colonies in the shrub layer. The vegetation was somewhat intermediate between mesic mixed hardwood forests of the valley floor and chestnut oak/heath forests of the ridge slope. There has been very little change in this plot since 2001. Almost all the trees and shrubs measured in 2001 were still present in the 2014 resampling, although a few low-cover herbaceous species from the 2001 sample were not observed. The growth of woody plants has resulted in a modest increase in basal area and stem density, including that of the dominant shrub, mountain-laurel. The beech component, indicative of the mesophytic conditions, continues to increase in the understory and should, over time, replace most of the oaks in the overstory.

Plot BULL051P/R

2001 Species Richness: 13
2014 Species Richness: 13
2001 Density and Basal Area: 850 stems/ha; 30.8 m^2/ha
2014 Density and Basal Area: 700 stems/ha; 35.5 m^2/ha

This East Ridge plot is similar to BULL050P/R (see Pine – Oak / Heath Woodlands Group) but is located on a sub-level crest and has many fewer pines. In 2001, the open chestnut oak (*Quercus montana*)-dominated forest had very low species-richness and nearly lacked herbaceous plants because of poor, dry, densely humus-mantled soils and intense competition from colonial ericads. Among the latter, black huckleberry (*Gaylussacia bac*cata) was the prevalent species, with mountain-laurel (*Kalmia latifolia*) and early lowbush blueberry (*Vaccinium pallidum*) also common. Judging from the number and size of charcoal fragments unearthed while collecting soil samples, past fires on this ridge were frequent and intense. This plot has changed only marginally since 2001. The two pitch pines (*Pinus rigida*) recorded in the earlier sample are now dead, and a couple of additional American beech (*Fagus grandifolia*) saplings have become established. Otherwise, floristic composition and relative species abundances have remained virtually static. Total basal area has increased only slightly, suggesting that tree growth is very slow on this dry, exposed site.

Plot BULL64P/R

2001 Species Richness: 16
2014 Species Richness: 18
2001 Density and Basal Area: 2875 stems/ha; 26.1 m^2/ha
2014 Density and Basal Area: 2475 stems/ha; 27.3 m^2/ha

The original forest on this slope was dominated by American chestnut (*Castanea dentata*) which apparently escaped cutting, or at least had attained large diameters, before succumbing to chestnut blight. In 2001, large, partly rotted chestnut boles covered the ground beneath a secondary mixed oak forest and very dense shrub cover of mountain-laurel (*Kalmia latifolia*). This chestnut "graveyard" is unusual in the Bull Run Mountains, where most forests were cut prior to the arrival of the blight; and it is valuable for reconstructing successional changes that have occurred in the post-chestnut forests of the area. In this stand, overstory successors included chestnut oak (*Quercus montana*), scarlet oak (*Quercus coccinea*), and black oak (*Quercus velutina*). No fire scars or charcoal were found at this site and many mountain-laurel stems were large (up to 10cm DBH), suggesting a long absence of fire. In 2014, we found that several small black oaks had died, and many stems of mountain-laurel had died or lost most of their foliage. The remaining trees have grown very little, and both woody stem density and basal area have remained almost static. Although there is some oak recruitment here, it is outnumbered by that of the fire-intolerant, mesophytic trees red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), and American beech (*Fagus grandifolia*).

Plot BULL072P/R

2001 Species Richness: 22
2014 Species Richness: 23
2001 Density and Basal Area: 800 stems/ha; 42.0 m^2/ha
2014 Density and Basal Area: 800 stems/ha; 52.3 m^2/ha

The sampling site is a gentle crest of High Point Mountain with dry, nutrient-poor soils and a history of fire. In 2001, the forest growth was a nearly pure stand of chestnut oak (*Quercus montana*), consisting of scattered old specimens (>65 cm DBH) and a cohort of younger trees 20 to 35 cm DBH. Excellent recruitment of this oak was also present in sapling and shrub-sized classes, but seedlings were not found. The deciduous heaths early lowbush blueberry (*Vaccinium pallidum*) and black huckleberry

(*Gaylussacia baccata*) dominated the shrub and herb layers. The tree component of this plot has changed little since 2001, except for the surprisingly strong growth of the greatly dominant chestnut oaks on this very dry and acidic site. Although a few of the smaller trees of this species have died, strong diameter growth among the larger trees has resulted in a nearly 25% increase in basal area over thirteen years. The estimated percentage of bare mineral soil substrate in this plot has increased from 5 to 10%, especially along a pronounced animal or anthropogenic social trail that runs north-south through the center of the plot. Additionally, the deciduous ericads that dominate a dense low shrub stratum have been greatly reduced in stature and cover by heavy deer browse. The cover of early lowbush blueberry has decreased from approximately 70% in 2001 to 40% in 2014, and that of black huckleberry has decreased from approximately 8% to 1%. No browsing impacts were noted in the original sampling.

PINE – OAK / HEATH WOODLANDS GROUP

Pine – Oak / Heath Woodlands are scattered on the driest ridges of the Bull Run Mountains, forming small to occasionally large patches that are estimated to cover about 100 hectares (240 acres) in aggregate. This community type is strongly associated with very xeric, infertile, convex slopes and rock outcrops with copious evidence of past fires. Most of the dominant pitch pines (*Pinus rigida*) and table-mountain pines (*Pinus pungens*) occur as even-aged cohorts that likely regenerated following catastrophic fires. Fire adaptations in table-mountain pine include serotinous, heat-responsive cones, while pitch pine exhibits both serotiny and the ability to sprout prolifically from fire-injured stems and branches. Virginia pine (*Pinus virginiana*), eastern white pine (*Pinus strobus*), chestnut oak (*Quercus montana*), and scarlet oak (*Quercus coccinea*) are frequent associates of the two pyrophytic pines. Trees are typically stunted and ericaceous species form a dense shrub layer. True herbs are very sparse or absent, except on rock outcrops where shrub cover is reduced. Communities of this group are self-maintaining on cliffs, where edaphic stresses reduce competition from hardwoods. On sites with deeper soils, however, little or no recruitment of pines has occurred for many decades following the widespread suppression of fires starting in the 1930's. Many of the area's pine-oak/heath woodlands are now undergoing canopy closure and slow but certain encroachment by chestnut oak and other oaks. A good indicator of fire exclusion in these woodlands is the increased presence of *Acer rubrum* (red maple) and/or *Fagus grandifolia* (American beech) saplings in the understory at all but one of the sampling sites. These thin-barked species are shade-tolerant, very susceptible to fire and, in the case of the mesophytic beech, decidedly out of place in the high, xeric habitats.

Plot BULL022P/R

2001 Species Richness: 17
2014 Species Richness: 20
2001 Density and Basal Area: 1550 stems/ha; 38.2 m^2/ha
2014 Density and Basal Area: 1875 stems/ha; 38.8 m^2/ha

This plot is situated on a convex, upper slope just below the crest of High Point Mountain. Substantial evidence of past fires (charcoal, tree scars) was noted in the very dry habitat. In 2001, chestnut oak (*Quercus montana*) was the most abundant overstory tree, but pitch pine (*Pinus rigida*) and Virginia pine (*Pinus virginiana*) were common associates that probably represented cohorts dating from a major fire; a very large, 68 cm DBH table-mountain pine (*Pinus pungens*) located just beyond the north edge of the plot contributed 5-10% overhanging cover. There were indications that the stand was once more open, with mixed oak and pine dominance, but young chestnut oak had become abundant in the understory, likely during a period of fire exclusion. The shrub and herb layers were dominated by mountain-laurel (*Kalmia latifolia*) and other ericads. Only two true herbaceous species occurred in the plot. By 2014, the stand had progressed even more toward complete dominance by chestnut oak and mountain-laurel.

The formerly co-dominant pine component had largely died out, with mortality of one pitch pine and five Virginia pines since 2001. It appears that most or all of this pine mortality was due simply to old age rather than southern pine beetles. Because of the concurrent growth of remaining hardwoods, total basal area is almost identical in the two samples. Since 2001, the density of measureable mountain-laurel stems has more than doubled, and the dieback of this species that has been widely observed elsewhere on Bull Run Mountain is absent here. This stand is unusual in having fairly numerous oak recruitment, and a paucity of understory red maple (*Acer rubrum*) and black gum (*Nyssa sylvatica*). However, many of the younger subcanopy oak trees are showing signs of stress and dieback, and American beech (*Fagus grandifolia*) has increased significantly in the shrub layer since the 2001 sampling.

Plot BULL024P/R

2001 Species Richness: 15
2014 Species Richness: 13
2001 Density and Basal Area: 1475 stems/ha; 34.7 m^2/ha
2014 Density and Basal Area: 1600 stems/ha; 42.1 m^2/ha

This plot is located on a xeric, very infertile, low-elevation ridge crest (Quarry Ridge) north of Thoroughfare Gap. In 2001, it supported an open, mixed forest of pitch pine (*Pinus rigida*) and oaks (*Quercus* spp.); pitch pine, however, was somewhat more important in the plot sample than in the overall stand. Thick duff and root-rich humus, along with dense rhizomatous colonies of black huckleberry (*Gaylussacia baccata*), severely limited herbaceous species and contributed to low (n = 15) overall species richness. Widespread patches of pitch pine, fire scars on the trees, and charcoal fragments in the soil all indicate a strong history of fire on this ridge. The only notable changes in the 2014 resample are that one pitch pine, one chestnut oak, and many stems of mountain-laurel (*Kalmia latifolia*) have died. Although it was not a dominant shrub species in 2001, mountain-laurel has decreased in cover from >5% to <1% in 2014. Stand basal area has increased considerably due to the diameter growth of the trees. There is little oak and no pine recruitment here, and the subcanopy continues to be dominated by black gum (*Nyssa sylva*tica), with some red maple (*Acer rubrum*) and American beech (*Fagus grandifolia*) also present. A larger number of sapling beech are invading the understory of this stand to the north of the plot. The entire stand is extremely fire-suppressed and could benefit from prescribed burning.

Plot BULL025P/R

2001 Species Richness: 15
2014 Species Richness: 18
2001 Density and Basal Area: 975 stems/ha; 34.8 m^2/ha
2014 Density and Basal Area: 875 stems/ha; 24/2 m^2/ha

This very dry, infertile, crest on the East Ridge, south of Hopewell Gap, burned approximately 30 to 40 years ago and almost certainly has a long history of periodic fires. One of the more extensive and well-developed pine-dominated forests in the Bull Run mountains occupies the site. In 2001, pitch pine (*Pinus rigida*), eastern white pine (*Pinus strobus*), and Virginia pine (*Pinus virginiana*) all occurred, with major associates of chestnut oak (*Quercus montana*) and the scrubby blackjack oak (*Quercus marilandica*). A very dense (>80% cover) shrub complex of mountain-laurel (*Kalmia latifolia*) and deciduous ericads grew beneath the stunted (max. height = 16 m) trees. About 10 cm of duff and root-rich humus covered rocky mineral soil at this site, nearly precluding the establishment of any herbaceous species. Only minor changes have occurred since 2001 in this stand, which remains an extremely fire-suppressed, pine-dominated forest. A few smaller pitch pines have died and there is some noticeable dieback of mountain-laurel stems, although the cover of both species remains high.

Some small (< 2.5 cm DBH) stems of both American beech (*Fagus grandifolia*) and red maple (*Acer rubrum*) are starting to become established. A tremendous build-up of dry, pine and ericaceous duff makes this stand highly susceptible to fires originating from lightning strikes or human-caused accidents.

Plate 9. Even-aged, semi-closed woodland dominated by pitch pine (*Pinus rigida*) and dense shrub colonies of black huckleberry (*Gaylussacia baccata*), on the East Ridge south of Hopewell Gap. Plot BULL025R, June 17, 2014.

Plot BULL032P/R

2001 Species Richness: 14
2014 Species Richness: 15
2001 Density and Basal Area: 2750 stems/ha; 42.1 m^2/ha
2014 Density and Basal Area: 1625 stems/ha; 36.4 m^2/ha

This plot is located on the very dry, convex, upper slope of the East Ridge near the boundary with Bull Run Mountain Estates. The site has a history of frequent or severe fires, soils are sandy and nutrient-poor, and the forest is floristically depauperate. In 2001, this plot captured what was essentially a small stand of dominant pitch pine (*Pinus rigida*) within a matrix of chestnut oak (*Quercus montana*)-dominated forest. Chestnut oak and other hardwoods comprised the entire understory. Since there was no pine recruitment, successional trajectory in the continued absence of fire or other disturbances appeared to be toward an oak-dominated forest over the long term. Mountain-laurel (*Kalmia latifolia*) formed an exceedingly dense shrub layer over nearly the entire western flank of the Bull Run Mountain East Ridge north of Hopewell Gap; only by positioning the plot in an area where the mountain-laurel was unusually thin (ca. 70% cover) could this vegetation be sampled. Since 2001, a new ATV trail was constructed by VOF stewards through the middle of the plot, running roughly north-south. One pitch pine and one chestnut oak were removed, and several mountain-laurels pruned to the ground, during

the construction. Several chestnut oak snags (including the original tag tree) were present in the 2014 resample, and branch dieback on mountain-laurel was very noticeable. In fact, the density of measureable mountain-laurel stems (>2.5 cm DBH) decreased more than 50%, in part due to this dieback. This quadrat might seem to be a poor candidate to maintain as a permanent plot; however, it may prove worthwhile to monitor and study the long-term influences of the fragmenting trail and other, more natural disturbances.

Plot BULL035P/R

2001 Species Richness: 16
2014 Species Richness: 14
2001 Density and Basal Area: 2600 stems/ha; 39.3 m^2/ha
2014 Density and Basal Area: 2800 stems/ha; 53.7 m^2/ha

Numerous tree scars and charcoal fragments suggest a history of frequent or severe fires on this infertile middle slope of the East Ridge above Jackson Hollow. In 2001, the vegetation was a mixed oak-pine forest with a tall mountain-laurel (*Kalmia latifolia*) shrub layer. Pitch pine (*Pinus rigida*), Virginia pine (*Pinus virginiana*), chestnut oak (*Quercus montana*), and scarlet oak (*Quercus coccinea*) were all relatively common. Pines were essentially confined to the overstory, likely representing a slightly older cohort which regenerated following a stand-killing fire. Chestnut oaks dominated the sub-canopy layers. Some pine mortality from the southern pine beetle outbreak of the early and mid-1990's was noted outside the plot. Based on the 2014 resample, there has been little change in this stand since 2001. Floristic composition in 2014 is very similar; only two herbs and a seedling of common persimmon were not redocumented, while woody stem density and basal area have increased somewhat as expected due to the growth of trees and saplings. The density of mountain-laurel stems is identical between the two samples, and none of the branch dieback commonly observed elsewhere on Bull Run Mountain is present. Due to the absence of pine recruitment, a future outbreak of southern pine beetles could very quickly turn the stand into a chestnut oak – black gum (*Nyssa sylvatica*) Forest.

Plot BULL50P/R

2001 Species Richness: 13
2014 Species Richness: 14
2001 Density and Basal Area: 1400 stems/ha; 35.7 m^2/ha
2014 Density and Basal Area: 1525 stems/ha; 46.0 m^2/ha

The plot is located on a dry, sloping crest along the East Ridge north of Thoroughfare Gap. This site appears to have a history of frequent and intense fires. Soils here are extremely acidic and nutrient-poor, with a thick mantle of root-rich humus containing numerous charcoal fragments. In 2001, the vegetation was an oligotrophic pine-oak forest with a moderately dense shrub layer of mountain-laurel (*Kalmia latifolia*). Overstory pitch pines (*Pinus rigida*) and chestnut oaks (*Quercus montana*) were less than 20 m in height and had a somewhat scrubby growth form. Oaks dominated the subcanopy tree layers. There was little pine recruitment and some recent mortality from southern pine beetle outbreaks on the ridge. Data collected in 2014 reflects very little change from conditions in 2001. No major tree losses occurred, and the growth of woody stems on this very dry site has been great enough to boost total basal area by more than 20%. The density of measureable (>2.5 cm DBH) mountain-laurel stems has also increased markedly, and new saplings of red maple (*Acer rubrum*) and black gum (*Nyssa sylvatica*) have become established in the plot. The nature of future disturbances will determine the successional trajectory of the stand. There is enough young chestnut oak recruitment present that a severe outbreak of southern pine beetles could hasten the transition from a pine-oak to a predominantly oak overstory. The stand is obviously quite fire-suppressed, and prescribed burning would likely encourage recruitment of pitch pines.

DISCUSSION AND RECOMMENDATIONS

Fleming (2002) discussed the changes in the Bull Run Mountains' landscape and vegetation in the 50 years since the completion of Allard and Leonard's floristic studies (1943, 1944b, 1952):

> As H.A. Allard began his lengthy botanical survey of the Bull Run Mountains in 1934, he was confronted with a landscape in transition following a number of area-wide disturbances. Less than twenty years earlier, the introduced fungal pathogen *Cryphonectria parasitica* had infected legions of *Castanea dentata* (American chestnut) trees, resulting in the rapid elimination of one of the area's dominant overstory species. Moreover, Allard (1942) described much of the remaining forest as "cut-over woodland" and noted that "even the older stands represent successional forests following many cuttings and burnings of the original primeval forest cover" (Allard 1961). Over much of the area, even in the nearly pure ridge forests of *Quercus montana* (chestnut oak), "enormous numbers" of *Carya* (hickory) saplings had appeared, apparently indicating the ongoing replacement of the former oak-chestnut forests with an oak-hickory association (Allard and Leonard 1943). *Fagus grandifolia* (American beech), however, while present in some of the mesophytic forests, had seemed to reach a "static condition," since little or no reproduction could be found anywhere. On the higher ridges, fires "which formerly were very frequent" in the area had "so completely destroyed the vegetative cover that very xerophytic conditions obtained" (Allard and Leonard 1944a). The vegetation of these habitats was limited to a few heaths, scrub oaks, and open *Pinus rigida* (pitch pine) groves, with mosses and great lichen colonies of *Cladonia* and *Cladina* spp. (reindeer lichens) leading the revegetation of exposed, sandy soils.
>
> The white-tailed deer (*Odocoileus virginianus*), so ubiquitous today, was absent or rare in the northern Virginia Piedmont in 1950 (Knox 1997), and even the gray squirrel (*Sciurus carolinensis*) was noticeably scarce in the forests of the Bull Run Mountains (Allard and Leonard 1943). The area's human population was also at a low ebb during this era of the Great Depression, and Allard found many homes and cabins "abandoned and left in ruins or burned" (Allard 1961). Extensive portions of the area, encompassing more fertile lower slopes and the interior valleys, had been cleared long ago and brought into cultivation. By the 1930's, however, these sites to a large extent had been abandoned and were reforesting through the usual successional stages. Some sites, probably abandoned as long ago as the Civil War, already supported pure forests of *Liriodendron tulipifera* (tulip-poplar), while "hundreds of acres" of more recently abandoned fields had reverted to scrub or grassland stages (Allard and Leonard 1944a). The overall condition of the Bull Run Mountains during Allard's tenure was perhaps best summarized by his statement that "at the present time there is probably no area in Virginia that shows more striking and beautiful stages of vegetation succession trending toward the climax forest than does this area" (Allard and Leonard 1943).

By the time of the 2001 study, conditions had changed dramatically. The varied successional forests described by Allard had advanced and matured, while mountain-slope fields had become reforested. Existing hardwood stands had grown notably and exhibited many compositional changes. Tuliptree stands that in the 1930's were "at least 50 feet tall" (Allard and Leonard 1943) now generally exceeded 35 m (115 ft) tall. The pulse of hickory saplings reported by Allard had matured and many had taken a position of canopy co-dominance in the area's current oak-hickory forests. Various combinations of oaks, hickories, and tuliptrees had filled in to replace the formerly abundant American chestnut; and far from being reproductively "static," American beech had become abundant in every age class of mesophytic forests and invaded the understories of even the driest ridgetop chestnut oak stands. This species, red maple (*Acer rubrum*), and black gum (*Nyssa sylvatica*) had become the dominant understory trees in oak forests that had little to no young oak recruitment (Fleming 2002).

At the same time, new threats to forest health that were unknown in Allard's day had emerged and greatly impacted the Bull Run Mountains' forests. These included exotic pathogens and insects such as the dogwood anthracnose fungus, hemlock woolly adelgid, and gypsy moth. Deer populations, aided by historical restocking and restrictive hunting regulations, had rebounded to levels that exceeded environmental carrying capacity (Knox 1997). Evidence of excessive herbivory was observed in 31% of the 2001 plot samples, affecting 41 species (8 woody, 33 herbaceous), primarily in the more mesic and fertile habitats of the area. In many stands, repeated browsing and grazing had reduced structural diversity, eliminated tree seedlings, reduced the vigor and cover of palatable forbs, and indirectly fostered the patch-dominance of unpalatable shrubs and herbs (Fleming 2002). While Japanese honeysuckle (*Lonicera japonica*) was the only non-native plant recognized by Allard and Leonard (1943) as a threat to native vegetation, by 2001 Japanese stilt grass (*Microstegium vimineum*) and a host of other exotics unknown to Allard had become invasive throughout the area. Additionally, other invasives described as "rare" or "infrequent" in the 1940's had become much more widespread and numerous (Fleming 2002).

Data from the plots resampled in 2012-2014 indicate that the disturbance regimes and trends identified in 2001 have continued unabated. As a general rule, trees have grown considerably larger over the last 13 years, even on dry ridge sites. Among the 40 plots, mean basal area increased by 6%, despite the fact that many of the largest trees recorded in 2001 had died or been blown down. Basal area increased in 30 plots, and decreased in 10 plots, primarily due to natural mortality or windthrow. The average basal area increase among the 30 plots with positive growth was nearly 21%. On the other hand, both stem density and species richness showed little significant overall change. Average species richness increased by three taxa, well within the range of normal species turnover. Species richness increased by an average of seven taxa in 26 plots, decreased by an average of five taxa in 13 plots, and stayed the same in one plot. Average stem density increased by only three stems/ha. Stem density increased by an average of 393 stems/ha in 14 plots, decreased by an average of 234 stems/ha in 24 plots, and stayed the same in two plots. The more dramatic fluctuations in species richness and stem density among plots could usually be correlated with local site and disturbance factors.

All of the disturbance regimes identified in the 2001 study are just as prevalent in the 2014 data. Table 2 lists the major categories of disturbances and the percentage of plots in each vegetation group and overall that exhibited measurable or observable impacts from them. Among all the 40 plots, close to half exhibited damage that worsened since 2001 from natural gap-forming disturbances (tree mortality, windthrow, etc.), invasive non-native plant populations, excessive deer grazing and browsing, and compositional changes stemming from fire exclusion and the decline of oaks and pines. More than 25% of the plots were heavily impacted by non-native pathogens or insects, primarily dogwood anthracnose. However, the gypsy moth damage that was widespread and ongoing in 2001 has largely ceased and was not seen in 2014. A dieback affliction of mountain-laurel (*Kalmia latifolia*) was documented in 23% of the plots and observed in other places during the 2014 field work. Since the exact cause of this problem is not known, it has been maintained in a separate category. Finally, minor anthropogenic disturbances such as ATV or social trails were found in three plots. Major issues with vegetation damage from overuse by hikers has occurred at High Point cliffs (Fleming et al. 2015, Fleming and Lott 2015), but such disturbances are rare in the set of permanent plots since most are well removed from trails or located in areas not open to the public.

The distribution of disturbance regimes among vegetation groups shows clear trends that correlate strongly with gradients of soil moisture and fertility. While invasive plants are very problematic in the seepage swamps, mesic forests, and oak-hickory/mixed oak forests, they are greatly reduced by the

drought-prone, infertile soils of the oak/heath forests and pine-oak/heath woodlands. Similarly, the two latter groups have little in the way of resources for white-tailed deer, while the three more mesophytic groups have an abundance of resources and are heavily impacted by deer. On the other hand, the percentage of plots exhibiting oak or pine declines and compositional changes related to fire exclusion increases progressively from the oak-hickory forests (43%) through the oak/heath forests (80%) to the pine-oak/heath woodlands (100%).

Table 2. Percentage of resampled plots in each vegetation group exhibiting significant disturbance impacts. Impacts are considered "significant" if the disturbance has measurably increased since the original 2001 plot sample, or has continued to exert strong influence on the vegetation since 2001.

Disturbance type	**Seepage Swamps Group (5 plots)**	**Mesic Forests Group (5 plots)**	**Oak-Hickory and Mixed Oak Forests Group (14 plots)**	**Oak / Heath Forests Group (10 plots)**	**Pine – Oak / Heath Woodlands Group (6 plots)**	**ALL PLOTS (40)**
Gap-forming disturbances (wind, ice, natural tree mortality)	0%	20%	79%	30%	67%	48%
Invasive non-native plants	80%	40%	79%	10%	0%	45%
Heavy deer grazing / browsing	0%	80%	64%	40%	0%	45%
Non-native pathogens and insects (dogwood anthracnose, hemlock adelgid)	0%	80%	36%	20%	0%	28%
Fire exclusion / oak or pine decline	0%	0%	43%	80%	100%	48%
Mountain-laurel dieback	0%	0%	7%	50%	50%	23%
Anthropogenic disturbances (trails, erosion)	0%	0%	7%	10%	17%	<1%

Sizeable canopy gaps that were not present in 2001 were documented in almost 50% of the resampled plots. These were mostly caused by natural mortality or blowdowns of large, old oaks, as well as some pines that died of old-age or possibly from southern pine beetle infestations. Disturbance from tree death, windthrow, and ice storms that create large gaps is a normal ecosystem function in mid- to old-

age forests that can benefit oak recruitment, understory diversity, and herbaceous vigor. However, the current condition of most forests in the area tends to preclude these effects, as the increased illumination primarily benefits the well-established understories of red maple, beech, and other mesophytic trees rather than oaks. Moreover, the soil disturbance and tip-up mounds that follow windthrow and large downfalls are great vectors for the spread of Japanese stilt grass, wineberry (*Rubus phoenicolasius*), Asiatic bittersweet (*Celastrus orbiculatus*), garlic mustard (*Alliaria petiolata*), and several other common, introduced, invasive plants.

Non-native weeds have measurably increased, in some cases by an order of magnitude or more, in 45% of the plots. This includes 80% of the seepage swamp plots, 40% of the mesic forest plots, and 79% of the oak-hickory/mixed oak forest plots. Plots that had no representation of a given invasive in 2001 but now have > 10% cover of it (e.g., BULL016R and BULL059R) are particularly instructive about the prolific reproductive abilities of these species. Data from the plots accurately reflect the pervasiveness with which Japanese stilt grass has spread and become dominant in many of the area's forests since 2001. Wineberry, Asiatic bittersweet, and garlic mustard are also spreading rampantly. Several other species, including autumn olive (*Elaeagnus umbellata*), multiflora rose (*Rosa multiflora*), Japanese barberry (*Berberis thunbergii*), climbing euonymus (*Euonymus fortunei*), Amur honeysuckle (*Lonicera maackii*), long-bristled smartweed (*Persicaria longiseta*), mile-a-minute (*Persicaria perfoliata*), and lesser celandine (*Ficaria verna*) are currently less common and/or more localized but have great potential to become widely invasive in forest understories. The control of non-native invasive plants – at least in critical habitats – is the single biggest biological stewardship issue on the Natural Area Preserve, as well as on private lands in the Bull Run Mountains. The 2004 management plan for the preserve (Leahy and Erdle 2004) stated that eradication is not a practical option for many well established invasive species, but that preventing the worst invasives from overrunning high-quality natural communities and preventing new invasives from becoming established on the preserve are viable objectives. Management efforts to date have fallen far short of achieving either objective.

The high levels of herbivory and woody plant browse by white-tailed deer encourage the spread of invasive species by reducing or removing competing native flora. Additionally, years of heavy selective grazing pressure on the area's forest communities have eliminated tree seedlings from many sites and created conditions of abnormally low herb cover and vigor over large areas that should have a robust herbaceous component. This is true even in the northern part of the Natural Area Preserve, where a VOF stewardship group maintains quite a number of tree stands and hunts regularly. Due to the logistical difficulties of conducting deer hunts in the publicly accessible, southern part of the preserve, only a few one-day managed hunts have been conducted there. In any case, it is clear that the existing hunting activities in and around the preserve have not reduced deer to a sustainable environmental carrying capacity. In order to do so, an accurate population census is needed, followed by a plan setting specific targets for population numbers per land area. The prescription given in the 2004 management plan still stands:

> .... the control of deer at BRMNAP will need a specific plan. VOF, DCR-DNH, BRMC, and VOF volunteer land stewards need to work with wildlife biologists from the Virginia Department of Game and Inland Fisheries (DGIF) through the deer management assistance program (DMAP) to development a deer management plan for the area .... The overall deer management goal will be to reduce impacts of deer on the abundance, flowering, and composition of the diverse vegetative ground layers found in the basic and mesic ecological communities at BRMNAP. This will likely occur when the local deer herd has been reduced and stabilized at < 20 deer/mi^2. (Leahy and Erdle 2004).

The dogwood anthracnose fungus (*Discula destructiva*) was encountered in about 25% of the resampled plots, in the form of standing dead or dying flowering dogwood trees. For all intents and purposes, this blight has nearly run its course in the Bull Run Mountains, and dogwood populations in forest understories have been reduced by probably 90% or more. Control of the fungus at a forest scale is not currently practical. Other pathogens and problem insects will likely affect the area in the future. Gypsy moth, which caused considerable oak mortality from the late 1980's until around 2002, appears currently under control by another naturalized fungal pathogen *Entomophaga maimaiga*, but this condition may change in the future. The Asian beetle emerald ash borer (*Agrilus planipennis*) is now well established in Virginia and decimating populations of several ash (*Fraxinus*) species, although it has not yet been detected in the Bull Run Mountains. Because ashes occur in relatively small numbers in the area's forests, it is possible that all three species occurring here – white ash (*Fraxinus americana*), black ash (*Fraxinus nigra*), and green ash (Fraxinus pennsylvanica) – could be nearly or completely extirpated by this pest. Stewards should also be alert for signs of beech bark disease, a complex involving both insect and fungal components that originated in Europe. Although most Virginia sites of forest-scale infection occur in the higher mountains, beech bark disease has also been found in a few isolated Piedmont localities (T. Dierauf, pers. comm.). See these web sites for more information:
http://www.dof.virginia.gov/health/guide/insect-disease-guide-hardwood.htm#Beech
http://www.na.fs.fed.us/fhp/bbd/

During the 2014 field work, a number of areas with noticeable to severe dieback of mountain-laurel (*Kalmia latifolia*) were noted. This phenomenon was recorded in half the plots of the oak/heath forest and pine-oak/heath woodland groups, where this shrub is a major component of the understory. The underlying cause of the dieback, which can afflict both individual branches and entire shrubs, is unclear and needs further investigation and evaluation by a plant pathologist. A fungal disease such as *Botryosphaeria* canker (Bush 2015) could be responsible, but similar symptoms may also result from winter injury or drought stress (Douglas 2011).

The oak/heath forests, pine-oak/heath woodlands, and likely other oak-dominated communities of the Bull Run Mountains developed under a regime of frequent presettlement and historical fires. Frequent fire was the key ecological factor that maintained suitable conditions for oak and pine recruitment and the long-term persistence of natural communities dominated by them. The positive influences of fire can be readily observed in the area of a small 2010 fire that burned on and behind the High Point cliffs, stimulating much woody and herbaceous regrowth (Fleming and Lott 2015). Although many details of the area's fire history are not known, there is ample evidence from plot data, literature, and long-time residents that fires were frequent up until the 1930's, but have been very infrequent since that time (Fleming 2002). Over the past 70 years or so, the absence of fire from most parts of the mountain have led to dramatic changes of forest composition, most notably the reduction or elimination of young oak and pine recruitment coupled with the invasion of forest understories by thin-barked, fire-intolerant trees such as red maple and American beech. In the most xeric pine-oak/heath stands, oaks are gradually replacing the pines. The ericaceous (heath) shrubs that dominate many of these communities are extremely well adapted to fire, and can become decadent unless burned back periodically.

The potential for utilizing prescribed fire management to maintain the quality of natural communities at Bull Run Mountains Natural Area Preserve is made difficult by the area's location adjacent to small and large residential tracts and the special expertise required to burn large acreages of Appalachian oak and pine vegetation. Leahy and Erdle (2004) felt that other natural area preserves with rarer natural communities were higher priorities for burning, given the limited resources of the DCR-DNH fire program. They concluded that "although at present DCR-DNH cannot begin planning and

implementation of prescribed fire management at BRMNAP, the issue will be revisited in five years .... " Twelve years have now passed since that was written, and the issue has not been revisited, at least formally. Although the logistics of conducting prescribed burns on the Natural Area Preserve remain as challenging as ever, the possibility of initiating a program of highly targeted prescribed burns could be explored. Certain sites in the preserve may be excellent candidates for fire management by virtue of their current condition and topographic setting. A good example would be the so-called "Quarry Ridge," which is located just north of Thoroughfare Gap and supports a classic pitch pine – oak / heath forest that is now being invaded by red maple and beech. This ridge lies between two large, wet hollows with streams and is bordered on the south by both a trail and the large railroad right-of-way, and on the north by the Ridge Trail – all of which provide good fire breaks. The area is small and also relatively accessible. For the most part, however, the inexorable transition of formerly pyrophytic forests to more mesophytic communities is a regional phenomenon of a magnitude that simply cannot be reversed by fire management. Sustaining some of the best examples of the Bull Run Mountains' oak/heath and pine-oak/heath communities with prescribed fire would be a worthy management goal; but for the most part, long-term management will have to recognize, accept, and plan for the long-term successional changes occurring over much of the area.

RECOMMENDATIONS

Listed below are some general recommendations related to urgent biological management issues that should be given consideration in future management planning. Their development and implementation will require cooperative planning and stewardship efforts between VOF, DCR-DNH, BRMC, PATC, and other parties as appropriate.

- **Update the Natural Area Preserve Management Plan**. The authors of the 2004 document stated that the plan was a guide to an adaptive resource management process and had a timeline of approximately five years (2004-2009). In the past twelve years, operational and biological management issues have evolved and, in some cases, changed. While many parts are still useful and applicable, the overall plan is somewhat out of date and needs revision. This presents an excellent opportunity to focus planning efforts and formalize decisions so that all stakeholders in the Bull Run Mountains are on the same page regarding management of the preserve.

- **Develop an invasive species management plan**. A plan that prioritizes and targets high-quality habitats for treatment of invasive species, and provides protocols for early detection and eradication of new invasive species, is badly needed.

- **Develop a deer management plan**. See comments above. This plan should focus on improving and maintaining the quality of vegetation in the area's mesophytic and oak-hickory forests.

- **Revisit the possibility of prescribed fire management in the Natural Area Preserve**. See comments above.

- **Develop protocols and stewardship resources for biological monitoring**. More frequent and systematic efforts are needed to monitor the condition of natural communities and detect new ecological/biological problems.

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APPENDIX
Detailed Plot Location Maps

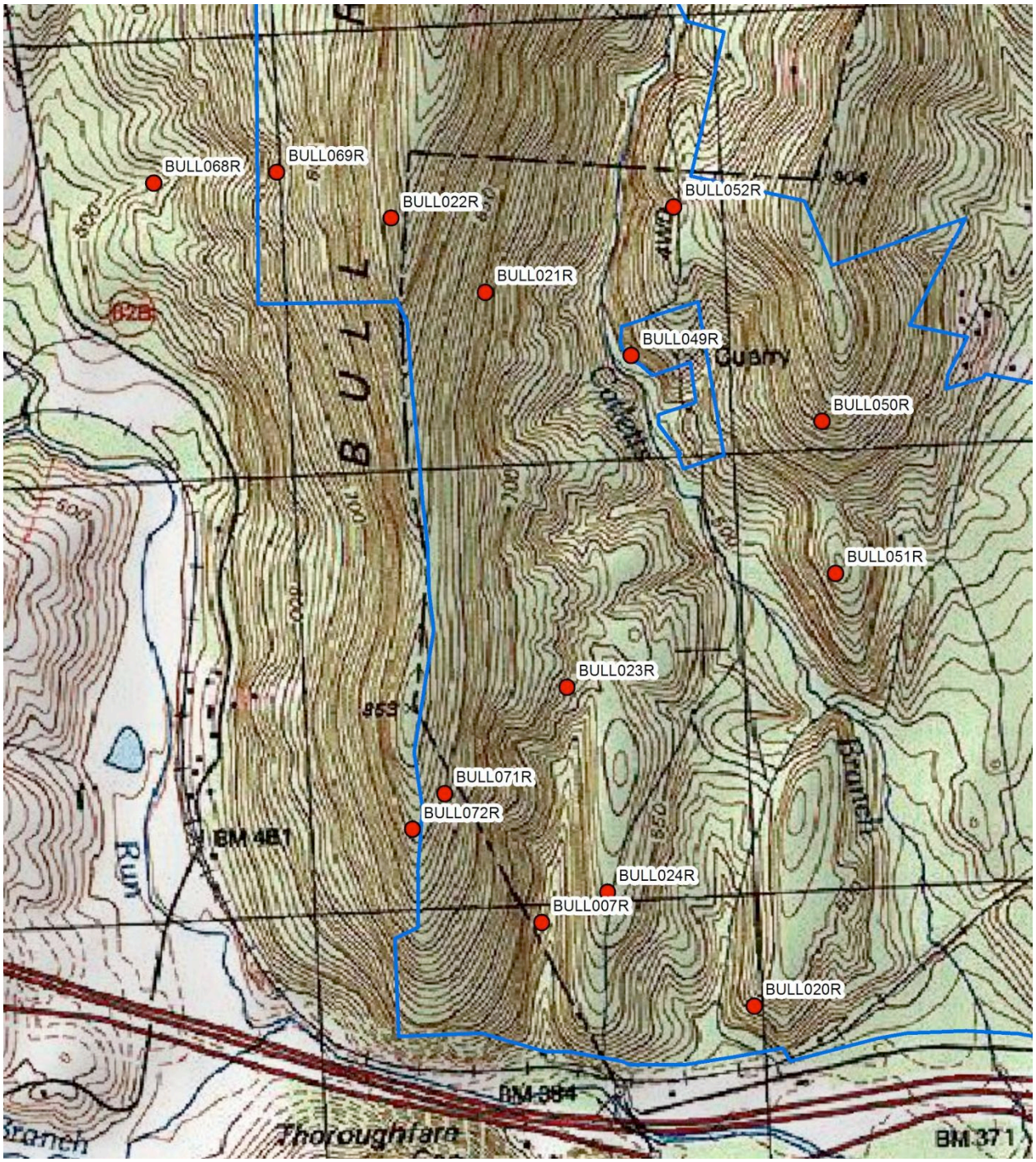

Fig. 2. Location of permanent plots in southern part of Bull Run Mountains: Thoroughfare Gap to High Point. Bull Run Mountains Natural Area Preserve boundaries are shown in blue.

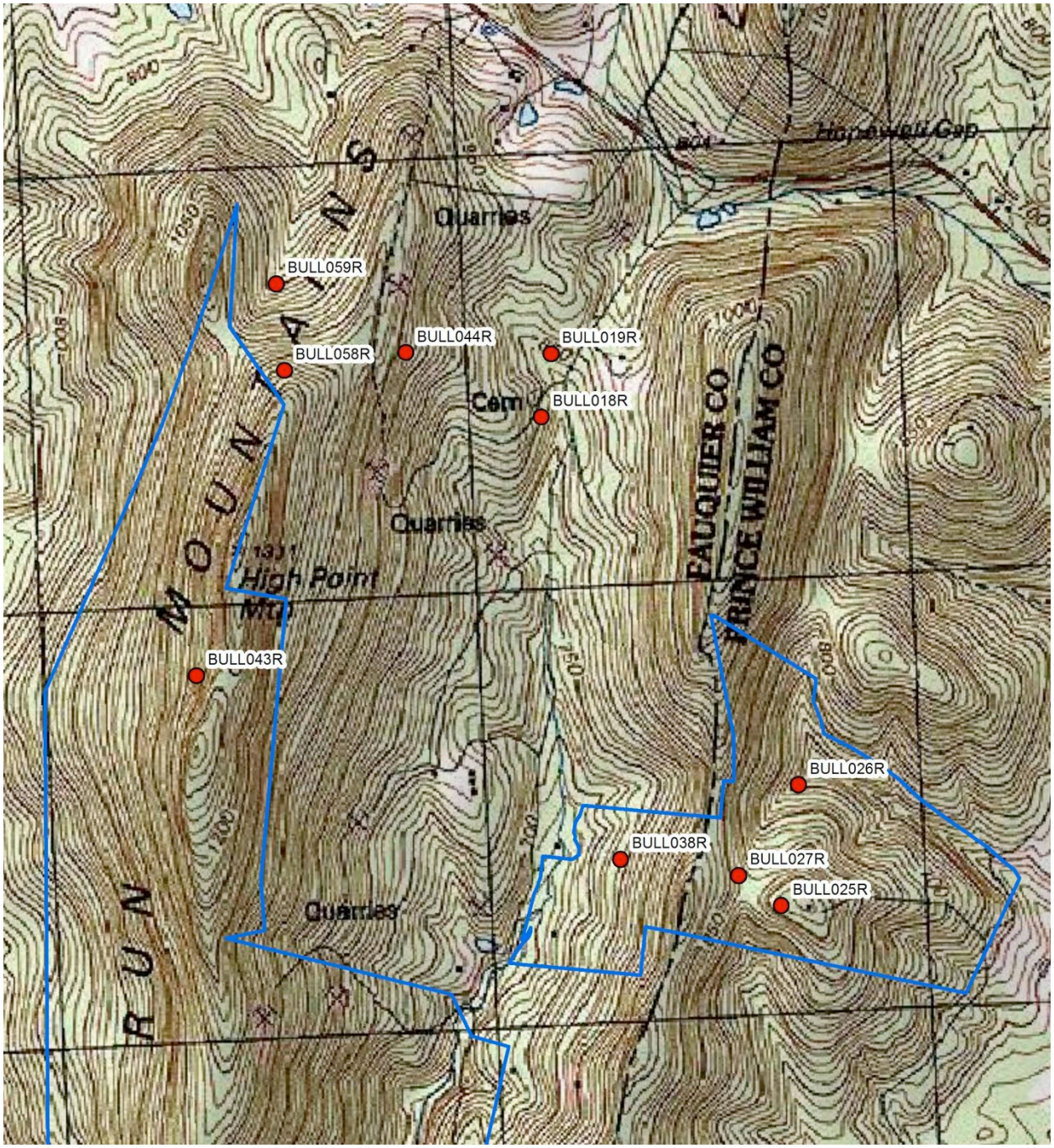

Fig. 3. Location of permanent plots in southern part of Bull Run Mountains: High Point to Hopewell Gap. Bull Run Mountains Natural Area Preserve boundaries are shown in blue.

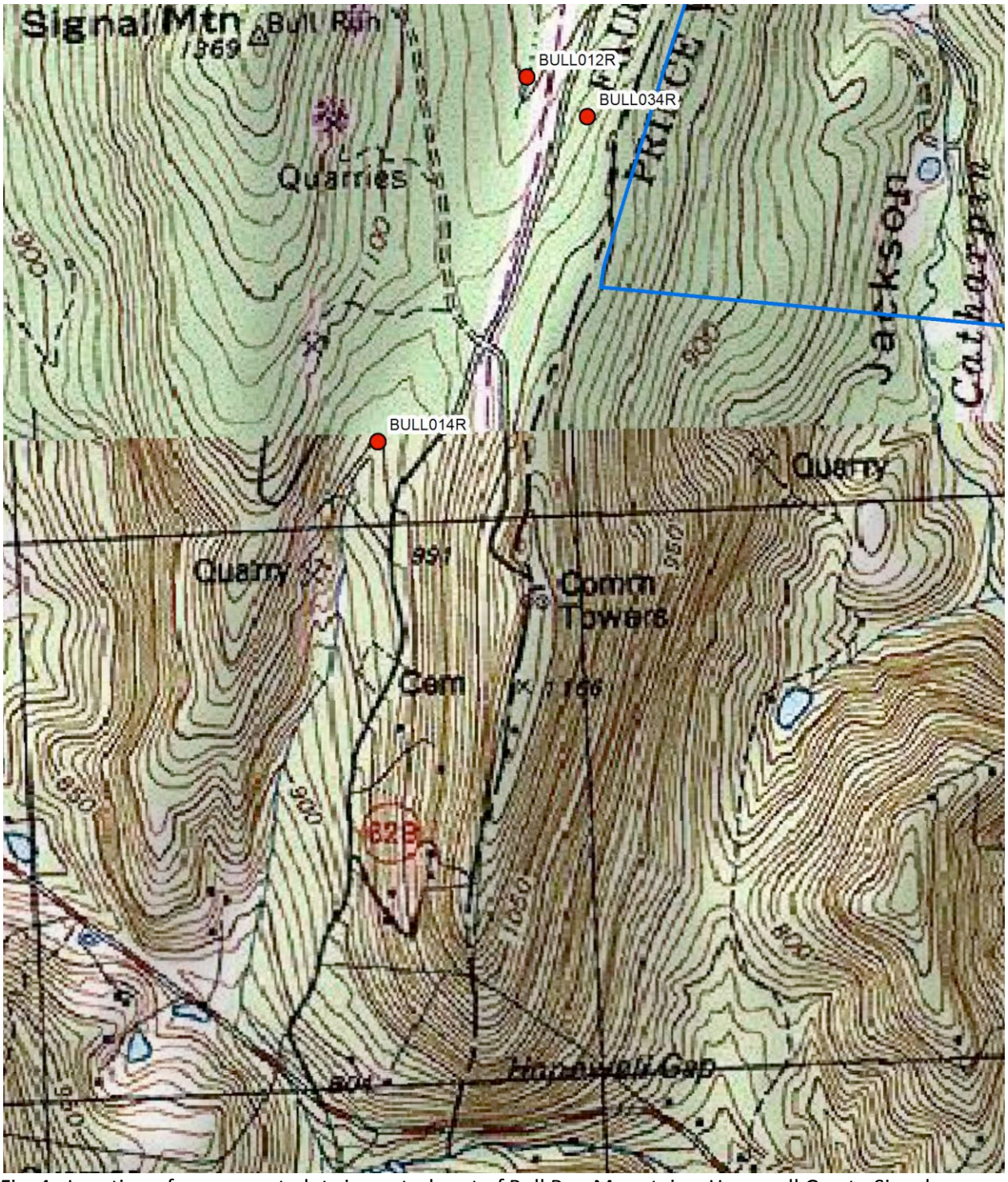

Fig. 4. Location of permanent plots in central part of Bull Run Mountains: Hopewell Gap to Signal Mountain. Bull Run Mountains Natural Area Preserve boundaries are shown in blue.

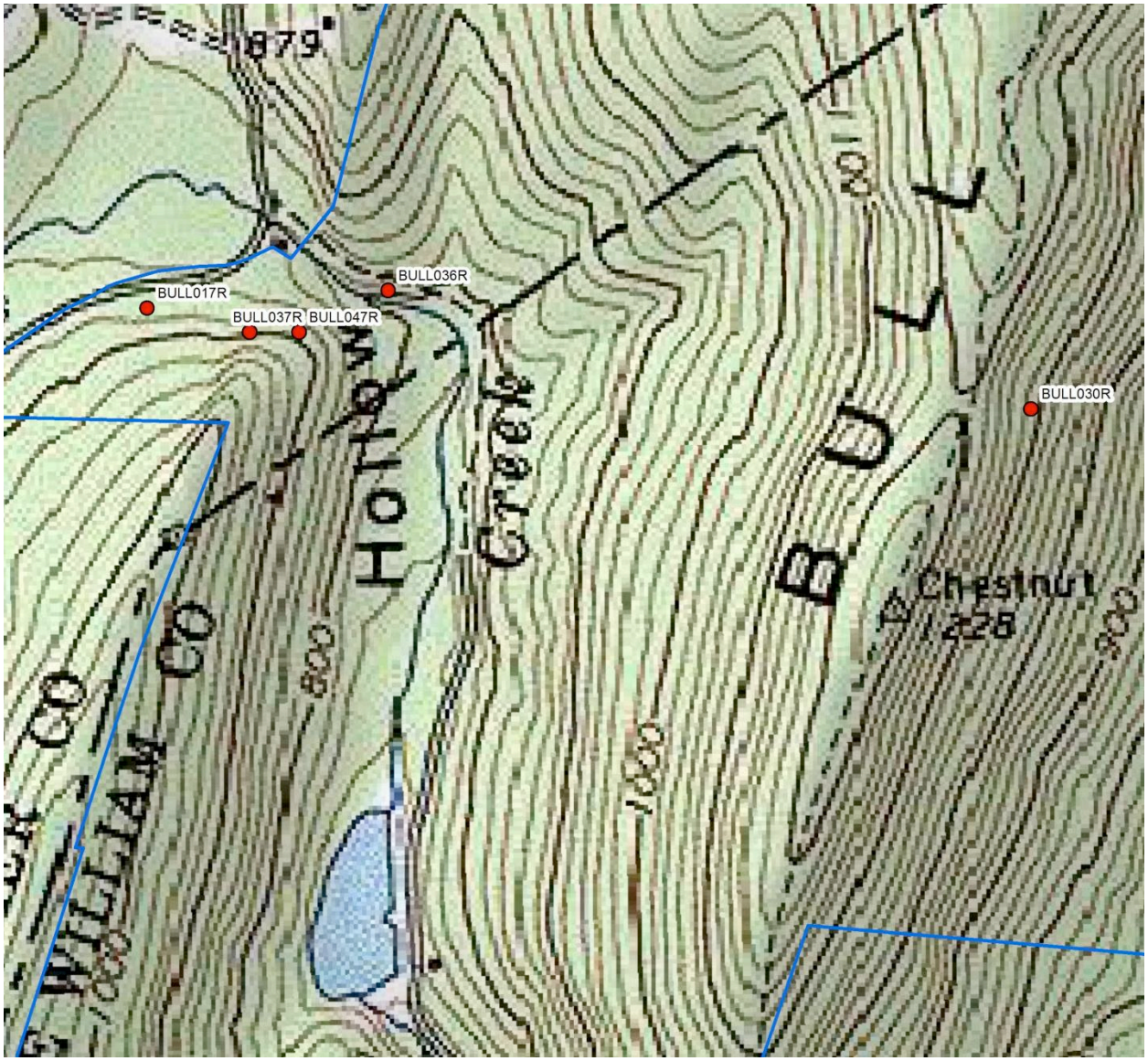

Fig. 5. Location of permanent plots in central part of Bull Run Mountains: Jackson Hollow area. Bull Run Mountains Natural Area Preserve boundaries are shown in blue.

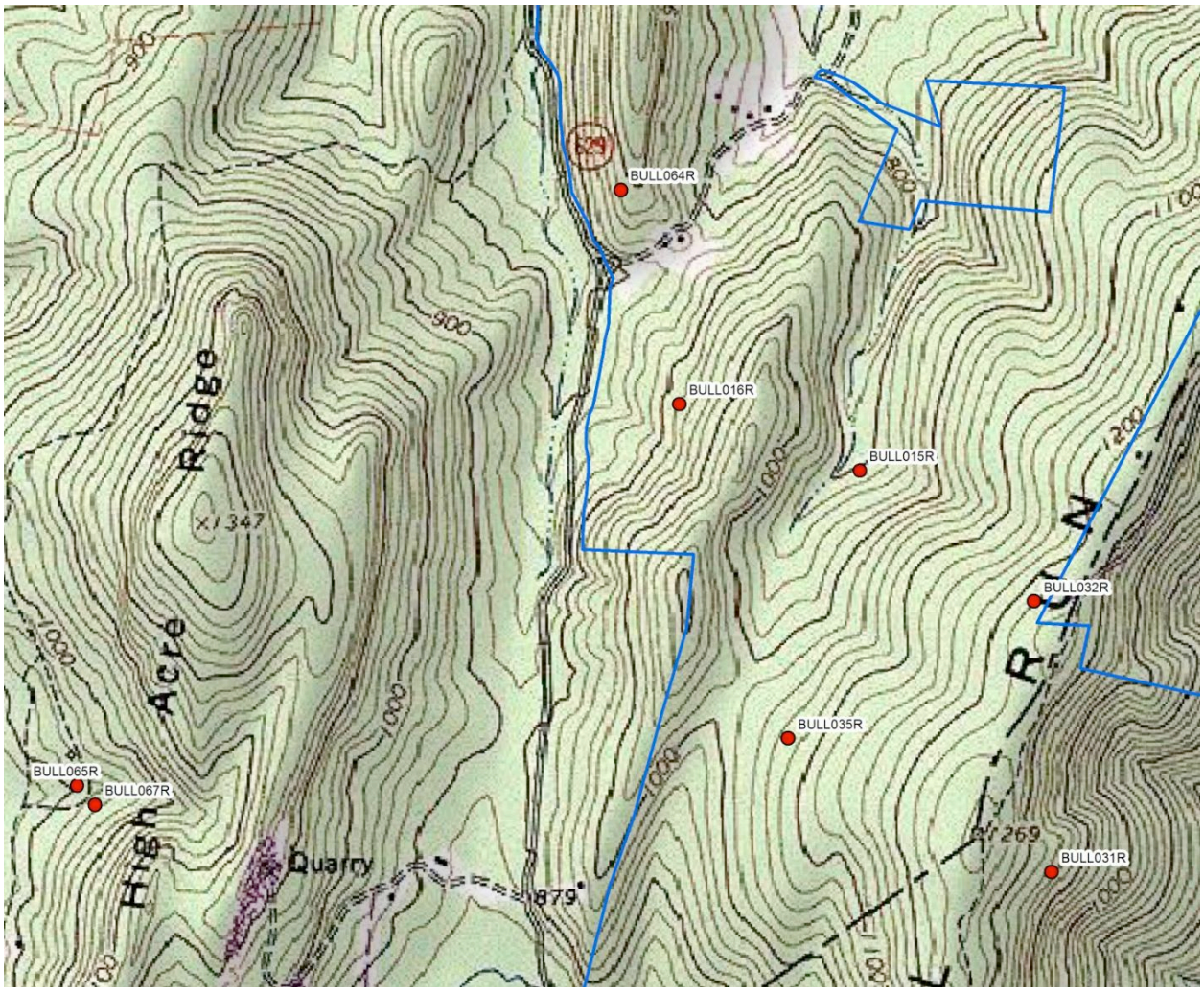

Fig. 6. Location of permanent plots in central part of Bull Run Mountains: High Acre Ridge-Bartons Creek-Hungry Run headwaters. Bull Run Mountains Natural Area Preserve boundaries are shown in blue.