Vegetation Dynamics of the Buck Creek Serpentine Barrens, Clay County, North Carolina

By

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A thesis submitted to the faculty of the University of North Carolina at Chapel Hill
in partial fulfillment of the requirements for the degree of
Bachelor of Science in Biology with honors.

University of North Carolina-Chapel Hill

Fall 2007

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Abstract

Serpentine vegetation is highly unusual, both due to vegetation structure and the presence of rare disjunct and endemic taxa. The open and well-drained conditions leave serpentine sites susceptible to more frequent fires and allow species more typical of open sites to thrive via low competition. The North Carolina Vegetation Survey initiated seven research plots at the Buck Creek serpentine barren in Clay County, NC in September of 1995. In April of that same year the US Forest Service began a prescribed fire management plan for the site. If the rare flora depend on both fire and soil chemistry, fire suppression may be reducing the success of the rare species associated with Buck Creek because the woody plants are becoming denser and shading out the rare plants. In order to test the interaction between fire and serpentine flora and thus assess the efficacy of the USFS fire management plan, six of the research plots were re-sampled. The soil and floristic data from the 1995 survey were compared with the more recent data. The introduction of systematic burning has reduced canopy individuals and led to the increased presence of rare and endemic species within the research plots.

Introduction

Research on the ecology of sites on serpentine soil spans the last half century and there is general agreement that the infertility of serpentine soils is largely a consequence of their chemical composition and, to a lesser extent, their physical attributes (Brooks 1987, Mansberg and Wentworth 1984). Serpentine, in the strict sense, refers to two specific minerals, both of which have the general chemical formula $Mg_3Si_2O_5(OH)_4$ (Brooks 1987). The term, however, is commonly used in a much broader sense to refer to extreme ultramafic rock.

Serpentine soils are infertile due to a variety of factors independent of climate or elevation. Specifically, these soils lack necessary nutrients, contain an excess of heavy metals, often at toxic levels, and potentially have lower soil moisture availability due to excessive drainage. While serpentine soils possess basic nutrient limitations including low nitrogen and phosphorus, there is an additional imbalance between calcium and magnesium. Calcium is relatively low compared to what are often high or toxic concentrations of magnesium (Brooks 1987). Chromium and nickel can occur in concentrations toxic to most plant species (Brooks 1987). Serpentine rocks are highly erodible under normal atmospheric conditions. The clays formed by the serpentine minerals adsorb more water than many other clay surfaces, but the location and terrain of sites like Buck Creek lead to lateral drainage to soils lower in the landscape leaving the soil relatively well drained (Alexander et al. 2006). This combination of factors reduces the ability of most plants to thrive on serpentine soils and has led to the presence a highly specialized flora.

Serpentine barrens are often exposed areas with dramatic changes in topography such as steep, highly erodible slopes (Mansberg and Wentworth 1984, Arabas 2000). The soils in these areas possess notable species diversity and a low number of non-native plants. Due to the extreme habitat conditions, non-native species tend to occur only in areas where the serpentine soils have been disturbed or altered such as through the addition of fertilizer, fire suppression, or invasion of the barrens by canopy species from the matrix forest (Chiarucci 1996, Barton and Wallerstein 1997, Arabas 2000).

Arabas (2000) suggests that fire suppression has played a major role in increasing the area of hardwood forest on serpentine bedrock in southern Pennsylvania. These closed-forest systems take over the open barren systems and shade-out the rare and unusual disjunct species of the herb layer. Arabas (2000) particularly noted that “soils may act as an abiotic ‘template’” that dictates the pattern of succession, and that changes in the disturbance pattern may influence soil development from the serpentine bedrock. Therefore, understanding the role of disturbance, and especially fire, is vital when attempting to preserve serpentine ecosystem structure and function.

Chiarucci (1996) and Barton and Wallerstein (1997) discuss invasion of *Pinus spp*. at different serpentine sites. Both studies suggest increased litter from these canopy species has strong effects on soil chemistry at the stand level. Barton and Wallenstein (1997) investigated *Pinus virginiana* as an invasive canopy species that alters “microenvironmental soil conditions,” and leads to stand level changes within serpentine communities. Their data show increases in soil depth and some macronutrients with increasing proximity to *P. virginiana* or increasing age and size of *P. virginiana* individuals. Like Arabas (2000), Barton and Wallerstein (1997) observed a transition from open savanna to closed late-successional forest and concluded, along with Chiarucci (1996), that canopy species can ameliorate the harsh soil conditions of serpentine barrens. Thus, it is important for any management plan enacted at a serpentine site to control the density and crown closure of canopy individuals.

Situated in Clay County, in the southwestern corner of North Carolina, Buck Creek is one of the southernmost serpentine barrens in eastern North America. Although not a site high in serpentine endemism, Buck Creek is home to several species disjunct from the main body of their native range (Mansberg and Wentworth 1984). According to Kauffman *et al*. (2004), the Buck Creek serpentine barren is the “largest and floristically and vegetationally most distinctive” serpentine site in the southern Appalachian Mountains. Effective management of the site is crucial to the preservation of the unique vegetation.

The US Forest Service owns and manages the Buck Creek serpentine barren. They recognize the conservation significance of the site and the importance of maintaining the unusual flora. Because the unusual flora appeared to be declining, and fire had elsewhere been implicated in such declines, the Forest Service introduced controlled burning in April of 1995. They hypothesized that an effective fire regime would reduce the number of canopy individuals and allow the light-demanding rare serpentine flora to regain a competitive advantage over the matrix flora of the region.

In order to test the interaction between fire and serpentine flora at Buck Creek, and evaluate Forest Service management practices, I compared sites that had been burned several times with those that had been burned less frequently. I also examined change in vegetation composition and soil attributes of plots sampled in 1995 and again in 2007.

Disturbance History

The Buck Creek serpentine barren was acquired by the United States Forest Service (USFS) in 1932 (Mansberg and Wentworth 1984) and has been under fire management since April, 1995 (Kauffman et al. 2004). Initially the site was divided into two burn areas labeled East and West. The site is currently divided into four burn areas labeled A through D (Figure 3). Each of the permanent research plots resides in one of the burn areas, and, as of 2007, each has experienced at least one burn (Table 1 and Figure 4).Aerial photographs of the area clearly illustrate the thin canopy and show some loss of the canopy after the first two burn events (Figures 1 and 2).

The East Buck Creek burn area comprises 102 acres and was burned in the spring of 2001 and the spring of 2004. Area A covers 40 acres and is located within the boundaries of the original East Buck Creek burn area. This section of the East Buck Creek unit underwent manual removal of targeted tree species (slashing) several years ago and has been burned twice since the initial slashing was done -- once in spring 2001, and again in spring 2004. The USFS management plan for East Buck Creek was written in 2001; a new plan is needed for future slashing and burning at this site.

West Buck Creek now encompasses 162 acres. The original burn area was approximately 55 acres and was last burned in spring 2003. It also received a slash treatment in 2002. The revised burn area will be expanded west up to Corundum Knob and south to Glade Branch. The expansion of Area D will take in the proposed Area B slash treatment. Area B comprises 40 acres and is located just south of the old West Buck Creek burn area.

The newest burn area is Area C. This unit consists of about 30 acres and is located west of Corundum Knob, just east of Chestnut Branch. The Chestnut Branch area covers 110 acres and is a new burn area that runs from Corundum Knob down the ridgeline to Perry Gap Road, along the road, and then up Chestnut Branch, back to the Barnett Creek Road. (See Appendix 3 for photographs of the area).

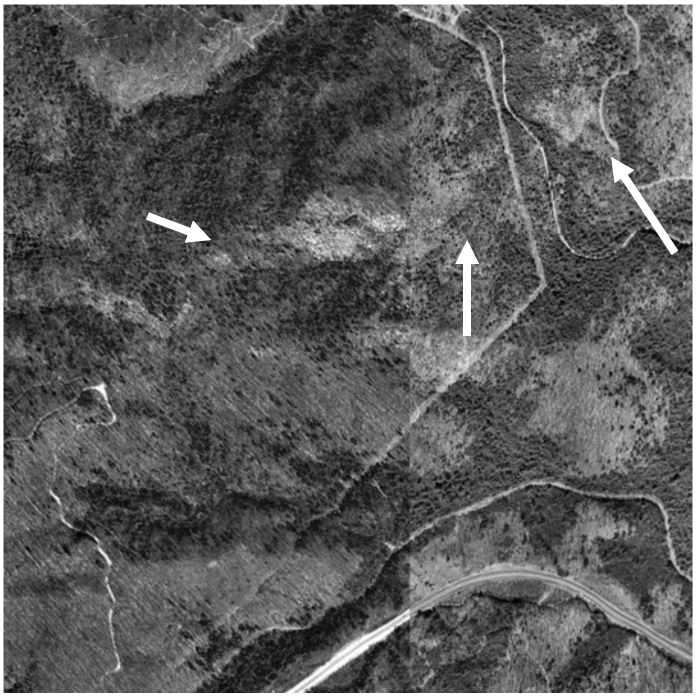

Figure 1: Aerial photograph of the Buck Creek Serpentine Barrens in 1994, one year prior to the first prescribed burn. The arrows roughly indicate the burn areas (Topozone 2003)

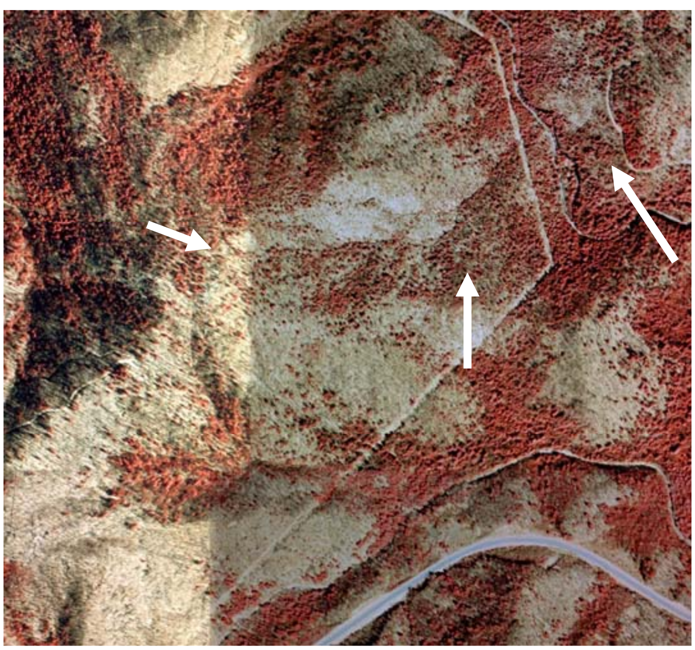

Figure 2: Infrared aerial photograph of the Buck Creek Serpentine Barrens in 1998, the two right-most arrows indicate areas which have now been burned. (Topozone 2003)

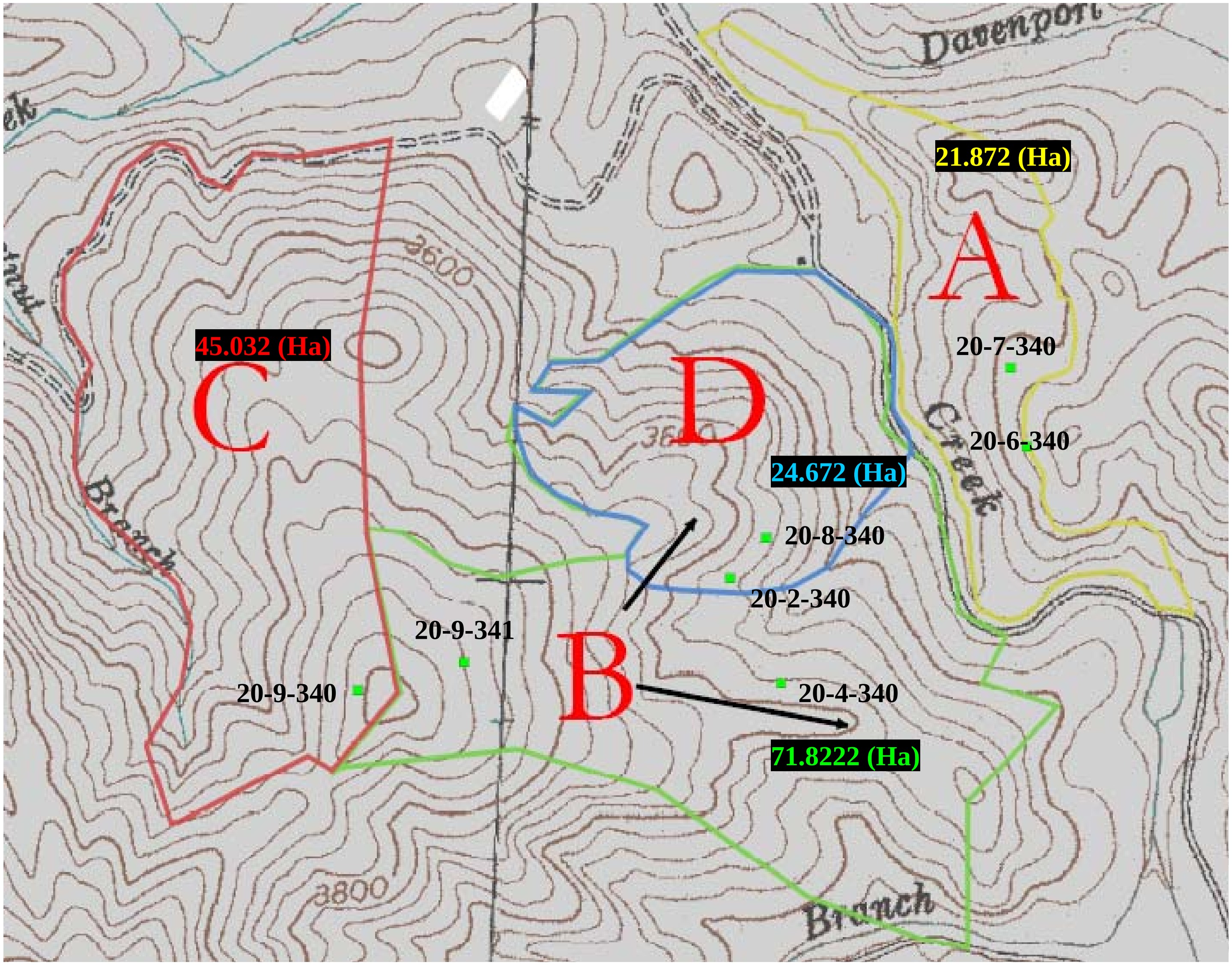

Figure 3: Map of the Buck Creek site showing the four main Burn Areas. The green dots indicate resampled research plots and are labeled with their Carolina Vegetation Survey plot numbers. The black boxes indicate the size of the burn area. Note that Burn Area B contains Burn Area D. (Kauffman, 2002)

Table 1: Burn and slash frequency information listed according to Plot Identification Number

PLOT ID	SITE NAME	BURN DATE 1	BURN DATE 2	BURN DATE 3	SLASH DATE
20-2-340	D	1995	1999	2003	2002
20-4-340	B	2006			2004
20-6-340	A	1997	2001	2004	2000
20-7-340	A	1997	2001	2004	2000
20-8-340	D	1995	1999	2003	2002
20-9-340	C	2007			2006
20-4-341	D	1995	1999	2003	2002
20-9-341	B	2006			2004

1875-1995	1875 Prospecting begins on Corundum Knob			1906 Prospect-ing on Corundum Knob is halted			1932 USFS acquires large area of the barren	1943 Brief period of prospect-ing					1st USFS prescribed burn
	1875	1885	1895	1905	1915	1925	1935	1945	1955	1965	1975	1985	1995

1995-2007 USFS Burns	Burn 1: Area D		Burn 2: Area A		Burn 3: Area D	Slash 1: Area A	Burn 4: Area A	Slash 2: Area D	Burn 5: Area D	Burn 6: Area A/ Slash 3: Area B		Burn 7: Area B/ Slash 4: Area C	Burn 8: Area C
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007

Figure 4: Timeline of Disturbance at Buck Creek

Methods

Study Site

The North Carolina Vegetation Survey established and sampled approximately 90 permanent vegetation plots in the Nantahala region of North Carolina in 1995 and 1996. Seven of these plots occurred on ultramafic soils of the Buck Creek barren. Six of these seven plots were relocated and resampled during summer 2007. All six of the resampled plots had burned at least once since 1995 as part of a US Forest Service management regime.

The Buck Creek Serpentine Barren is located on the north eastern border of Clay County with Macon County, North Carolina approximately one mile north of Highway 64. The site was left relatively undisturbed after the US Forest Service acquired much of the land in 1932. Prior to the 1995 fire the site had not experienced significant fire since the 1940s (Mansberg and Wentworth 1984). Buck Creek is home to many rare North Carolina species and at least two endemic species that thrive in open areas of the barren.

Table 2 shows that each of the permanent research plots possesses soil and physical characteristics typical of serpentine including low calcium to magnesium ratio, shallow soil, notable amount of clay, and occurrence on moderate slopes (Kruckeberg 1992, Mansberg and Wentworth, 1984).

Table 2: The above data show that the seven permanent plots have soil and physical characteristics known to be typical of serpentine barrens.

Plot ID	Average Ca/Mg (ppm)	Average Soil Depth (cm)	Clay %	Slope (deg)
20-2-340	0.39	22.8125	9.28	15
20-4-340	1.017	24.5	15	16
20-6-340	.705	19.8125	7	20
20-7-340	.8	33		15
20-8-340	.675	9.5625		34
20-9-340	1.6125	22.125		22
20-4-341	.79	11.5833	7	18

Sampling Methods

Plot Setup: Five of the six plots were 20m x 50m rectangles containing ten 10m x 10m square modules. The modules are numbered 1-10 (Figure 5). The sixth plot was a 10m x 30m rectangle containing three 10m x 10m square modules (Figure 6).

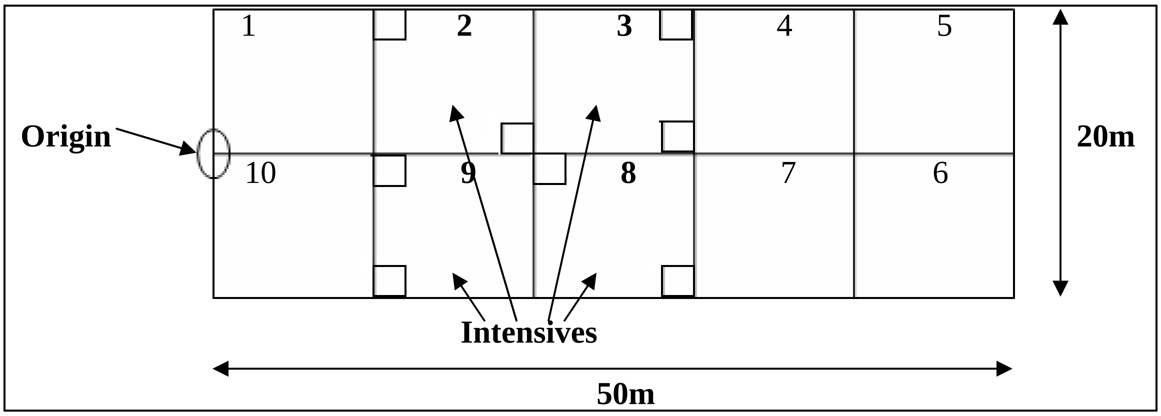

Figure 5: Schematic of a 20m x 50m plot. The boxes in the corners of the intensive modules show the location of the nested sampling areas within the module.

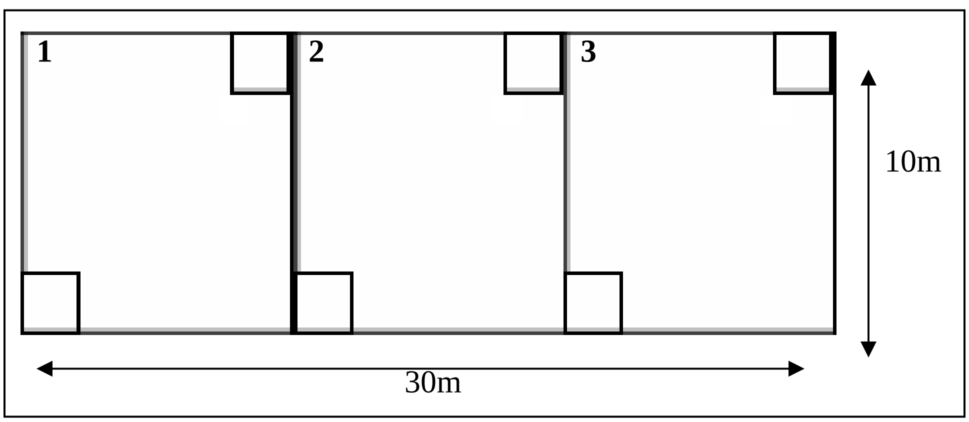

Figure 6. Schematic of a 10m x 30m plot. All three modules were intensives with nested sampling corners.

Intensive Modules: For the five 20m x 50m plots, modules 2, 3, 8, and 9 were intensive modules and for the sixth plot all three modules were intensive. Each intensive module was sampled individually for presence of vascular plant species in a series of five nested scales ranging in size from $0.01m^2$ to $100m^2$ (Figure 7). Cover values were also estimated but not used for analysis. Woody individuals taller than breast height (1.4m) were tallied within each intensive module according to diameter (cm) at breast height (DBH).

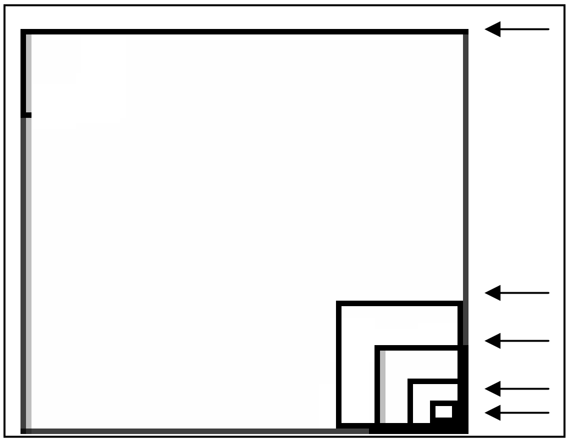

Figure 7. Nesting. The nested corners are as follows: $0.01m^2$, $0.1m^2$, $1.0m^2$, $10.0m^2$, $100.0m^2$.

Residual Modules: The “residual” (non-intensive) modules were searched as one sampling unit for presence of herb layer species not found in the intensive modules. Woody species were tallied in the same way as for the intensive modules.

Soil: Soil samples were collected from the A and B horizons of each module and assayed for nutrients and texture by Brookside Labs, New Knoxville, Ohio. One composite sample of the A horizon was created per intensive module by combining four cores (from the module being sampled). One composite sample of the B horizon was created per plot by combining four cores (one from each intensive module). Therefore, six soil samples were assayed for each 20m x 50m plot and four samples were assayed for the 10m x 30m plot.

Previous Sampling Data and Taxonomic Considerations: The data from 1995 were provided by the North Carolina Vegetation Survey. The 2007 resampling was conducted using the same protocol as the four teams that surveyed the seven original plots in 1995. Botanical nomenclature follows Weakley (2006). Radford et al. (1968) was consulted for aid in identification.

Sampling Limitations: The original purpose of the North Carolina Vegetation Survey plots was to sample the species present in all different areas of the barren (along the stream bed, at high elevation on Corundum Knob, along steep inclines, within the area affected by pine beetles, facing east, and facing west). However, these plots were not specifically designed to capture rare species. Therefore, while these plots do provide pre and post-fire data, they are not ideal for sampling rare herb species. Moreover, due to the nature of vegetation sampling, the comprehensiveness and accuracy of the survey of each plot is limited by the botanical expertise of the surveyor. Although many plant samples were collected for identification, it is not possible to be sure that plants identified in the field were correctly identified, nor is it possible to assume that all species present within the plots were recorded.

Results

Soil:

Several soil factors contribute to floristic composition on serpentine. Factors analyzed as part of this study can be broken into three categories. The first category is general soil characteristics, which includes organic matter, cation exchange capacity, and pH. The second is for nutrients, specifically nitrogen, potassium, and phosphorus, the values of which are characteristically low at serpentine sites (Brooks 1987). The third category includes soil calcium, magnesium, and their ratio, which is considered crucial to the uniqueness of serpentine vegetation (Brooks 1987). These soil data are summarized in Figures 8-14. In each case soil data from 1995 is compared with data from 2007. Soil samples from both survey years were analyzed in the same laboratory employing the same techniques, albeit twelve years apart.

All three categories of soil data show a general trend of reduced or stable values. In rare cases there were slight increases, as in the case for pH in most plots, and for magnesium and phosphorus in Plot 20-4-341.

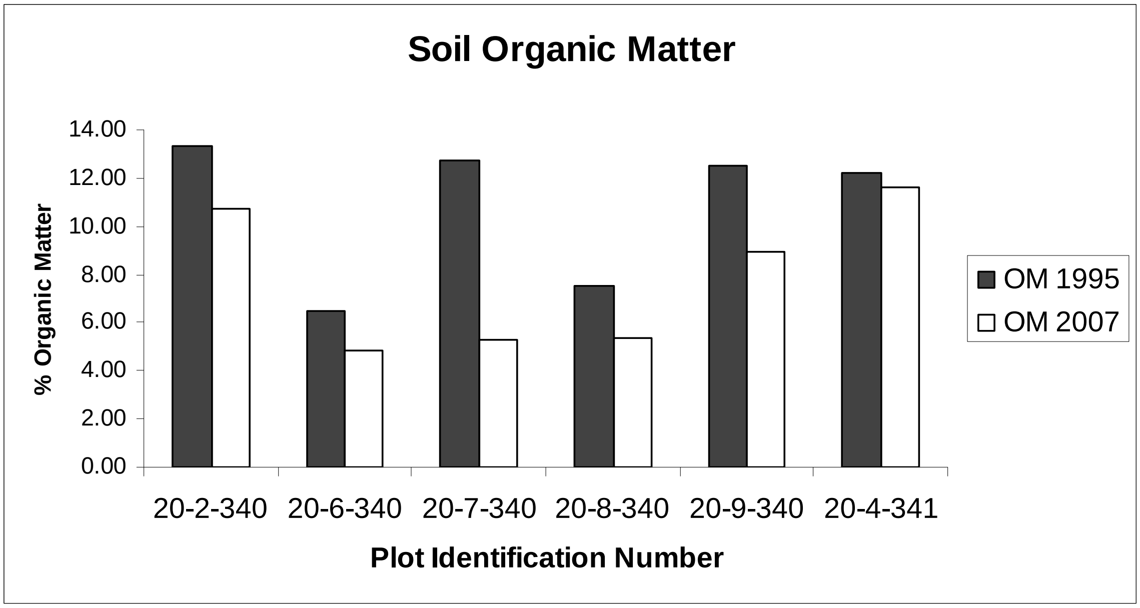

Figure 8: The percent of organic matter in the A horizon of each intensive module was reduced across all plots.

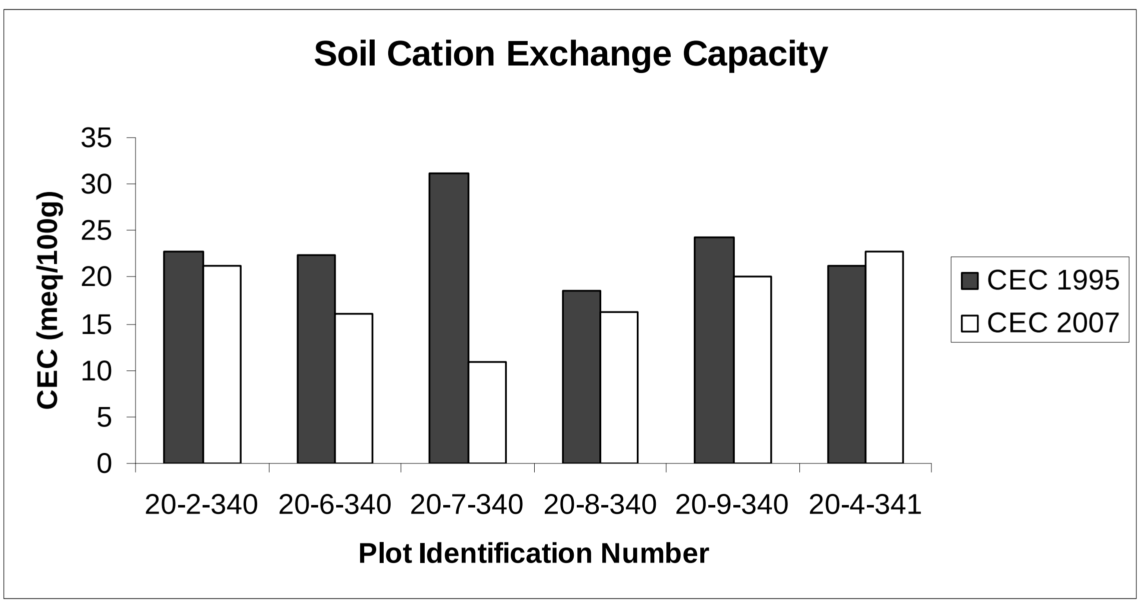

Figure 9. The cation exchange capacity (meq/100g) was reduced in five of the six plots.

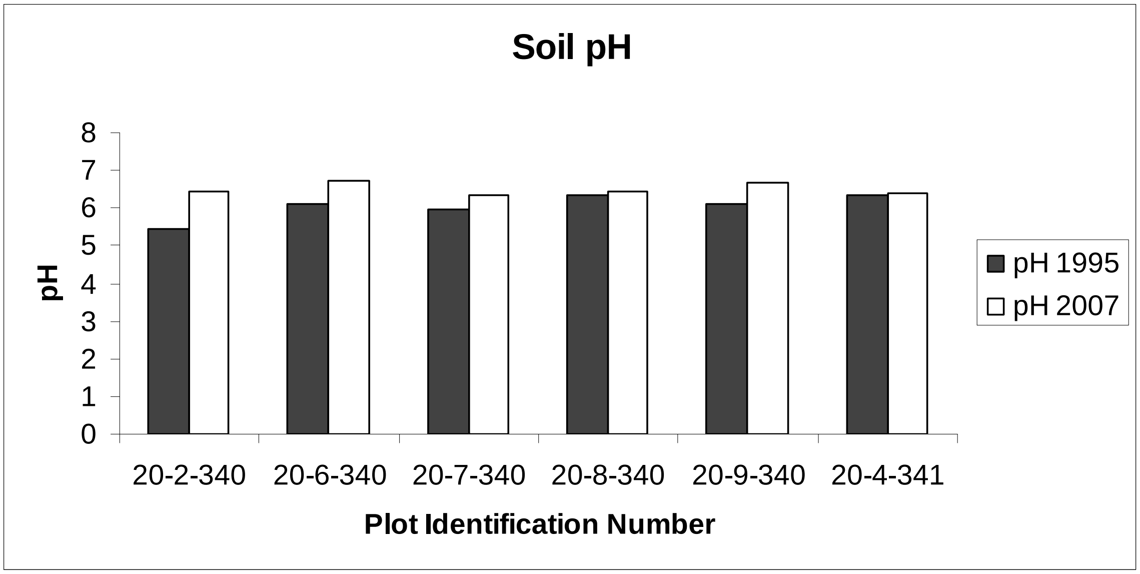

Figure 10: Soil pH remained fairly stable but was increased across all six plots.

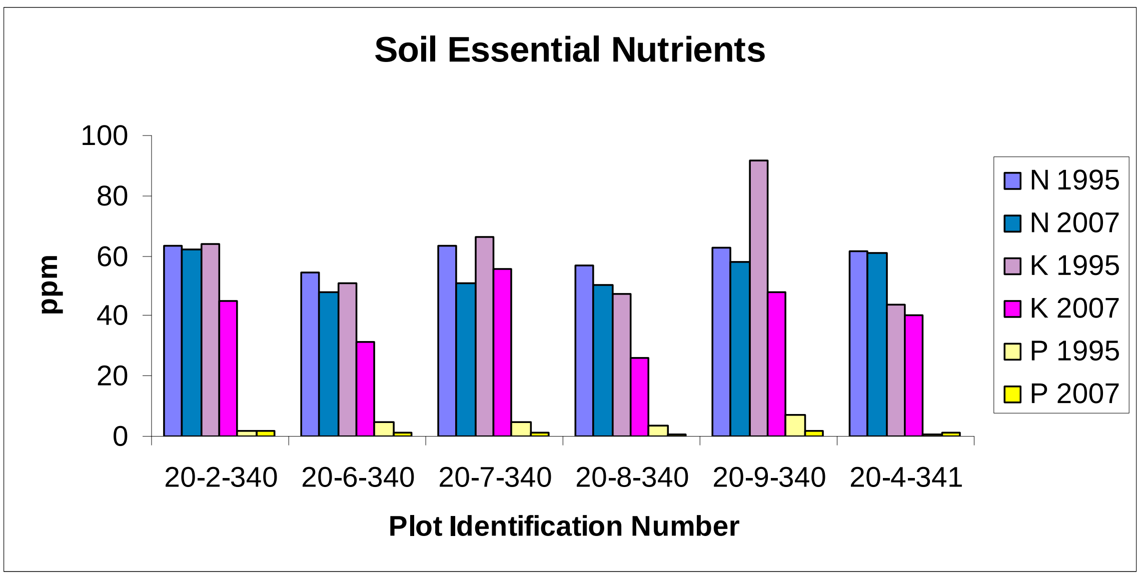

Figure 11: Soil nitrogen, potassium, and phosphorus levels (ppm) were reduced slightly to significantly across all six plots except in 20-4-341 where phosphorus increased slightly.

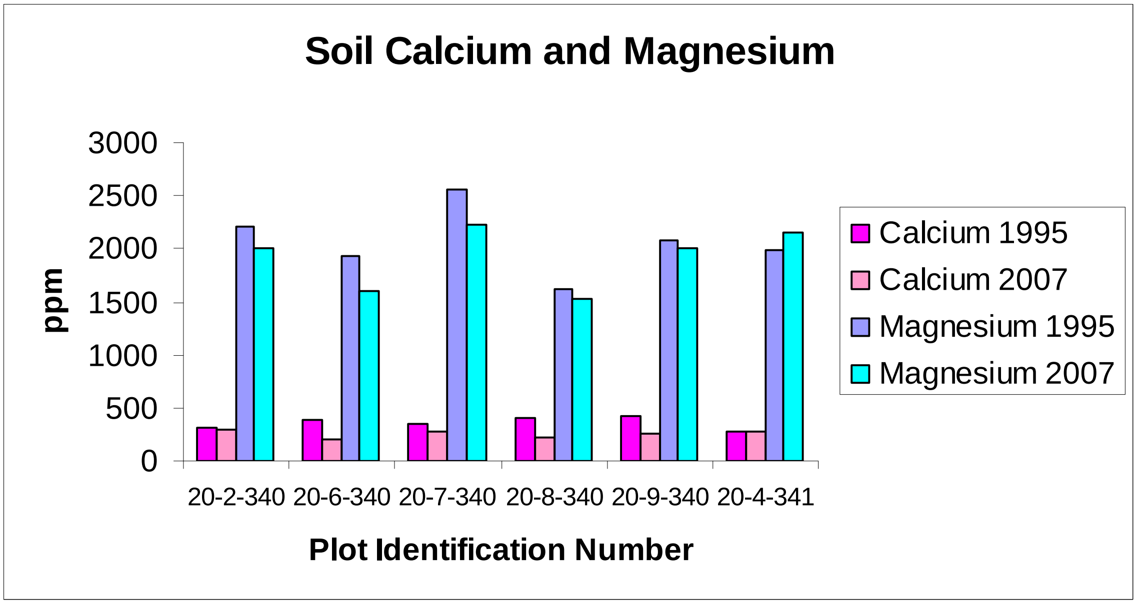

Figure 13: Both calcium and magnesium (ppm) were reduced across five of the six plots.

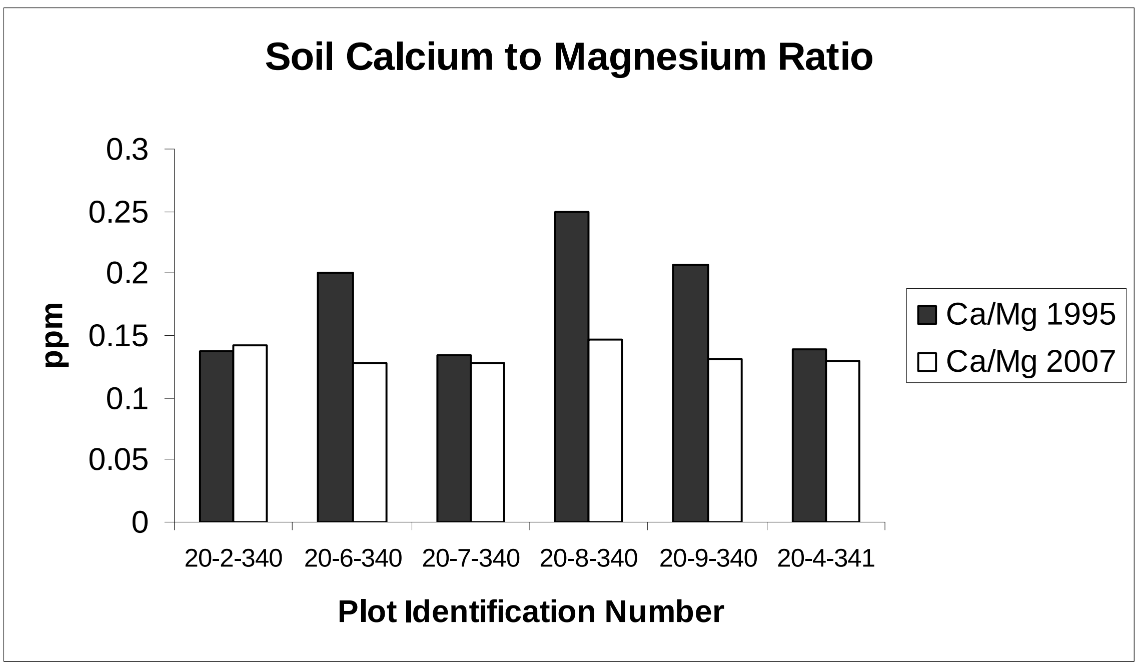

Figure 14: The calcium to magnesium ratio remained stable for two of the plots, was reduced for three of the plots, and significantly increased in one of the plots.

Vegetation:

In 1995, 138 species were present in the six plots. In 2007 I recorded 124 species (See Appendix 1 for the complete species list). Table 3 lists species that were lost from the 1995 survey and those that were added during the 2007 survey. Six of the nine species added are rare in the state of North Carolina, while only three of the twenty-five species lost are rare.

Woody individuals were reduced significantly across most species found at the site. In particular, *Acer rubrum* var. *rubrum*, *Pinus rigida*, *Quercus alba*, *Sassafras albidum*, and *Tsuga canadensis* experienced the greatest reductions, as shown in Figure 15.

Larger woody individuals were also reduced. The relative changes in the number of woody individuals of a particular size class (greater or less than 10cm at breast height, or 1.37 m above ground) are shown in Figures 16 and 17. In the case of *Amelanchier arborea*, one individual appeared in the larger size class in 2007 despite not being present in 1995. All other species showed reduced numbers of larger individuals when compared with the 1995 data.

Presence or absence within the intensive modules was used to quantify increase or decrease among herb layer species. There were 23 intensive modules within the six resampled plots. The frequency of occurrence of species within the intensive modules in 1995 is illustrated in Figure 18. Six species were present in all 23 intensive modules while 44 species were occurred in only one module. The general trend of species abundance in Buck Creek follows the log-normal relationship first proposed by Preston (1948): as the frequency of occurrence decreases, the number of species which achieve that frequency of occurrence increases. This general trend was also upheld by the 2007 data as shown by Figure 19.

Figures 18 and 19 demonstrate several trends. First, species that are disappearing from one module are often showing up in another and remaining stable in the area, specifically as species in columns 10 and 11. Second, species that were widespread in 1995 (those present in greater than 90% of the modules) remained stable if they were rare (e.g., *Hexastylis arifolia* var *ruthii*, *Packera plattensis*, and *Thalictrum macrostylum*) and were reduced if they were secure (*Vaccinium stamineum*, *Smilax glauca*, *Pinus rigida*). Third, more species experienced large reductions (moved more than two columns to the right) than those which experience large increases (moved more than two columns to the left). Finally, occurrence of increase and decrease is not restricted to species that are widespread or species which are highly restricted within the area. That is, species that were present in a large number of modules experienced just as much increase and decrease as species present in a small number of modules.

Rare species also experienced both increase and decrease regarding frequency of occurrence in intensive modules. Table 4 lists rare species by their rarity status according to NatureServe. A rarity status of 1 indicates that a species is endangered in the state of North Carolina; a status of 2 indicates that a species is imperiled, and a status of three indicates that a species is vulnerable. Four of the endangered species found within the plots were decreased in presence while six remained stable or were increased in presence.

Table 4 shows that overall, there were more rare species that were increased or stable than were decreased. Of the 33 rare species found in the plots, 12 species had decreased, five remained stable, and 16 increased in presence in the intensive modules.

Figure 20 compares species richness on the east facing slope and the west facing slope. Data from two upslope plots were used to describe each slope: on the east facing slope plots 20-2-340 and 20-8-340 were used, and two plots on the west facing slope plots 20-6-340 and 20-7-340. Both slopes have been subjected two three burns and one slashing treatment since 1995, albeit at slightly different intervals (Table 1). While the east facing slope maintained a higher richness value than the west facing slope, it experienced a greater loss in species richness (11% loss) between 1995 and 2007.

Figure 21 shows the number of species which decreased, increased, or remained stable between 1995 and 2007 on each slope. The two slopes show opposite trends. The east facing slope shows an increasing pattern with 20 decreased species, 34 increased species, and 46 stable species. The west facing shows a decreasing pattern which is slightly less pronounced with 29 decreased species, 20 increased species, and 21 stable species. (See Appendix 2 for a complete list of species and their change in frequency of occurrence).

Table 3: Species Lost/Species Added. The left hand column lists species that were present during the 1995 survey, yet were not present (lost) during the 2007 survey. The right hand column list the species that were not present during the 1995 survey yet were present (added) during the 2007 survey. In total, 25 species were lost, 9 species were added. *Rare species are indicated with an asterisk.

Species Lost	**Species Added**
Andropogon ternarius	Amelanchier laevis*
Aureolaria virginica	Calamagrostis poteri ssp. porteri*
Dichanthelium depauperatum	Eubotrys recurva
Diospyros virginiana	Hieracium scabrum*
Gentianopsis crinita*	Hypoxis hirsuta
Goodyera pubescens	Oenothera perennis*
Helianthus atrorubens	Ranunculus fascicularis*
Ilex montana	Rudbeckia hirta
Ilex opaca var. opaca	Viola appalachiensis*
Liriodendron tulipifera	
Nyssa sylvatica	
Phlox carolina	
Pinus strobus	
Polypodium virginianum	
Polystichum acrostichoides var. acrostichoides	
Prenanthes serpentaria	
Prunus serotina	
Quercus velutina	
Solidago curtisii*	
Stellaria pubera	
Symphyotrichum laeve var. concinnum*	
Tsuga canadensis	
Vaccinium erythrocarpum	
Viola sororia	

Woody Vegetation Taller than Breast Height (1.4m):

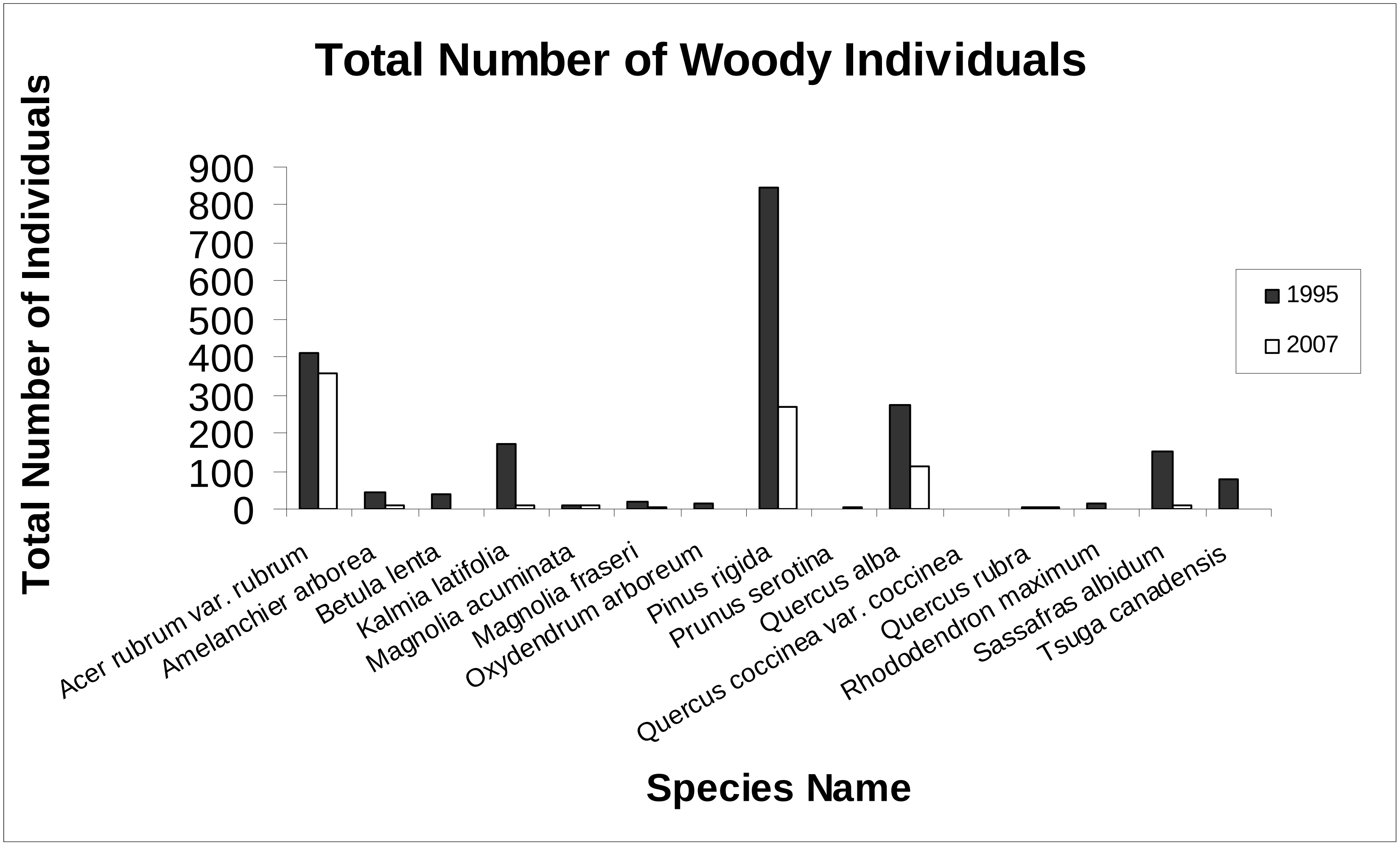

Figure 15: Most species experienced significant reduction in number of individuals, (e.g., *Pinus rigida*, *Quercus alba*, *Acer rubrum var. rubrum*, and *Sassafras albidum).*

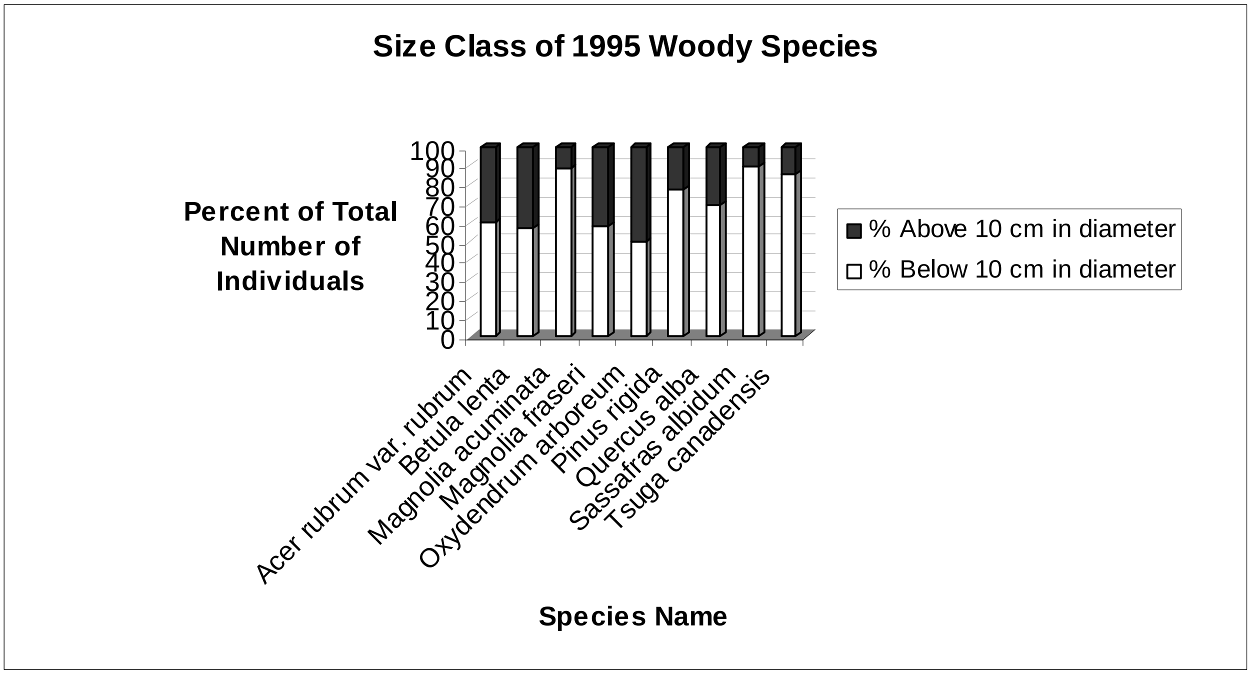

Figure 16: Size-class distributions of woody species, 1995. Nine species had individuals greater t >10cm DBH. More than 10% of the population within the plot was greater than 10cm DBH for each of these species.

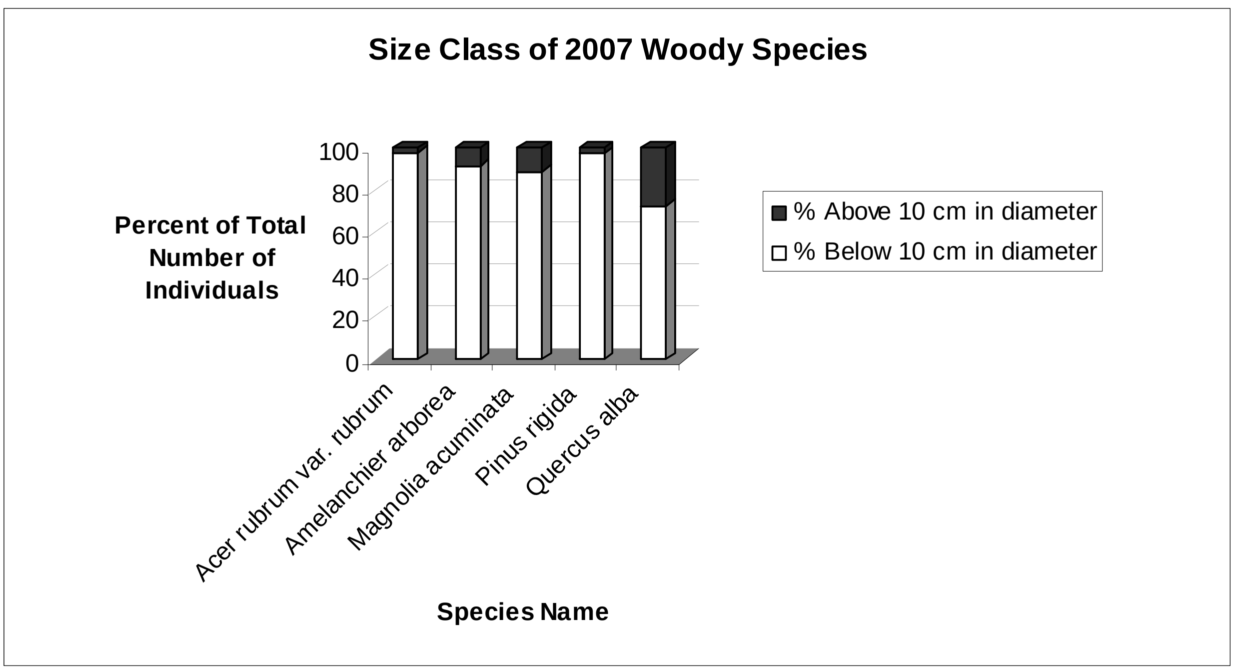

Figure 17: Size class distribution of woody species, 2007. Only five species had individuals >10cm DBH. The percentage of the population within the plot at that diameter was greatly reduced for most species (except *A. arborea,* which increased).

Herbaceous Vegetation and Woody Vegetation Shorter than Breast Height:

Percent Presence: Herb Species Listed by the Percent of Intensive Modules in which They Are Present (1995)

										AGPE 9
										ANTE 9
										ANVE 9
										CAPE 9
										CACO 9
										CHMA 9
										GAUR 9
										HOPUP 9
										POSA 9
										POTR 9
										RHMA 9
										SAAN 9
										SMHE 9
										STGRM 9
									ASVE 17	ANGYG 4
									CARO 17	ARPUP 4
									CHLU 17	AUVI 4
									DIVI 17	BAVI 4
									ERHIH 17	CEAM 4
									EUCO 17	CIMU 4
									GAPR 17	CYAC 4
									HIPA 17	DICL 4
									POACA 17	DILA 4
									RHVI 17	GECR 4
									RUCA 17	GOPU 4
									SYLAC 17	HEAT 4
									SYPH 17	ILMO 4
							HEMI 39		SYRH 17	ILOP 4
							HOSE 39		ZIAP 17	LAFLY 4
							SACA 39		ANVIV 13	LITU 4
							VAPA 39		DECA 13	LYQU 4
							VASI 35		DIAC 13	MAFR 4
							ASPLP 35		DISP 13	MIRE 4
							DEFLF 35		DIVIV 13	NYSY 4
							OXRI 35		GABA 13	OEFRG 4
							PAAN 35		MAAC 13	PHLA 4
						CADI 48	TSCA 35	BELE 26	PHCA 13	POCO 4
					OEFR 57	DICO 48	CAECE 30	EPRE 26	PHHE 13	POVI 4
		QUAL 87			PTAQL 57	KALA 48	PAGR 30	LYLIL 26	PRSE 13	QUVE 4
HEARR 100		SAAL 87			SMRO 57	POPA 48	SONEN 30	FEOV 22	SCAS 13	SCPA 4
PAPL 100		DIDID 83			SOBI 57	PRVU 48	SPALL 30	FESU 22	STBI 13	SOCU 4
SMGL 100	ACRUR 96	SCSC 83	AMAR 74		PAVIV 52	COMA 43	SYLAL 30	LOPU 22	THTR 13	STPU 4
THMA 100	ANGE 96	SONU 83	DASP 74		SYUN 52	MUGL 43	VACO 30	OXAR 22	VICU 13	VAER 4
VAST 100	PIRI 91	SPHE 83	ELTR 74	PHOPO 61	VINUC 52	QURU 43	VISA 30	QUCOC 22	VIPE 13	VISO 4
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**

Figure 18: Percent presence (1995) -- Herb layer species are listed by their USDA abbreviations and are clustered by the percent of the total number of intensive modules (23) in which they are present. Six species were present in all 23 intensive modules in 1995: *Acer rubrum* var. *rubrum*, *Hexastylis arifolia* var. *ruthii*, *Packera plattensis*, *Smilax glauca*, *Thalictrum macrostylum*, and *Vaccinium stamineum*. In general more species inhabit fewer intensive modules but the trend is slight.

Percent Presence: Herb Species Listed by the Percent of Intensive Modules in which They Are Present (2007)

										AGPE 9
										ANVIV 9
										ASVE 9
										CAPE 9
										CHLU 9
										FEOV 9
										FESU 9
										HOPUP 9
										LAFLV 9
										LYQU 9
										MAAC 9
										OEFRG 9
										PAAN 9
										SAAN 9
										SCPA 9
										SIVI 9
										SMHE 9
										VIPE 9
										AMLA 4
										ANGYG 4
										ANVE 4
										ARPUP 4
									DEFLF 17	BAVI 4
									CACO 17	BELE 4
									DICL 17	CAPOP 4
									EPRE 17	CARO 4
									GABA 17	CEAM 4
									LOPU 17	CIMU 4
									POSA 17	CYAC 4
									RHVI 17	DILA 4
								CADI 26	SCAS 17	ERHIH 4
							ASPLP 39	CAECE 26	VISA 17	EUCO 4
							DECA 39	OEFR 26	CHMA 13	EURE 4
							HEMI 39	OXRI 26	DIAC 13	HISC 4
							MUGL 39	PRVU 26	DISP 13	HYHI 4
							SOBI 39	QURU 26	DIVIV 13	MAFR 4
							SYRH 39	SONEN 26	GAUR 13	OEPE 4
							VINUC 39	SONU 26	MIRE 13	PHLA 4
							RUCA 35	SPALL 26	OXAR 13	QUCOC 4
			AMAR 78				HIPA 30	VACO 26	PAGR 13	RAFA 4
			DIDID 78	PIRI 65			HOSE 30	GAPR 22	PHHE 13	RHMA 4
ANGE 100			SCSC 78	SYUN 65			LYLIL 30	SYLAL 22	STBI 13	RUHI 4
HEARR 100			DASP 74	ELTR 61		SMRO 48	POPA 30	SYPH 22	SYPR 13	VIAP 4
PAPL 100	ACRUR 91	SMGL 83	SAAL 74	PTAQL 61	DICO 57	COMA 48	SACA 30	VAPA 22	THTR 13	VICU 4
THMA 100	SPHE 91	VAST 83	QUAL 70	PAVIV 61	KALA 52	PHOPO 43	STGRM 30	ZIAP 22	VASI 13	XEAS 4
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**

Figure 19: Percent presence (2007). Four species were present in all 23 intensive modules in 2007: *Andropogon gerardii*, *Hexastylis arifolia* var. *ruthii*, *Packera plattensis*, and *Thalictrum macrostylum*. The general trend of more species inhabiting fewer intensive modules persists, but is less consistent than in 1995. The table is color coded to show change in percent presence for a species: Red = ~30% increase, Orange = ~ 20% increase, Yellow = ~10% increase, Green = ~10% decrease, Blue = ~20% decrease, Purple = ~30% decrease.

Table 4: Change in presence of rare species. This table lists species that have a North Carolina Rarity Status of 1 (endangered), 2 (threatened), or 3 (vulnerable) (NatureServe). In total, twelve species decreased in presence four of which are endangered and one is possibly extirpated. Five species remained unchanged, one of which is endangered. Sixteen increased, five of which are endangered.

	Species Name	Number of Intensives 1995	Number of Intensives 2007	Change	NC Rarity Status
Decrease	Symphyotrichum laeve var. laeve	7	5	-2	SH
	Carex echinata ssp. echinata	7	6	-1	1
	Elymus trachycaulus	17	14	-3	1
	Gentianopsis crinita	1	0	-1	1
	Muhlenbergia glomerata	10	9	-1	1
	Parnassia grandifolia	7	3	-4	2
	Polygala paucifolia	11	7	-4	2
	Spiraea alba var. latifolia	7	6	-1	2
	Symphyotrichum laeve var. concinnum	4	0	-4	2
	Houstonia serpyllifolia	9	7	-2	3
	Sanguisorba canadensis	9	7	-2	3
	Solidago curtisii	1	0	-1	3
No Change	Packera plattensis	23	23	0	1
	Cirsium muticum	1	1	0	2
	Hexastylis arifolia var. ruthii	23	23	0	2
	Thalictrum macrostylum	23	23	0	2
	Physalis heterophylla	3	3	0	3
Increase	Calamagrostis poteri ssp. porteri	0	1	1	1
	Poa saltuensis	2	4	2	1
	Ranunculus fascicularis	0	1	1	1
	Sporobolus heterolepis	19	21	2	1
	Symphyotrichum rhiannon	4	9	5	1
	Oenothera perennis	0	1	1	2
	Stenanthium gramineum var. micranthum	2	7	5	2
	Viola appalachiensis	0	1	1	2
	Amelanchier laevis	0	1	1	3
	Castilleja coccinea	2	4	2	3
	Gaylussacia ursina	2	3	1	3
	Hieracium scabrum	0	1	1	3
	Rubus canadensis	4	8	4	3
	Symphyotrichum phlogifolium	4	5	1	3
	Symphyotrichum prenanthoides	0	3	3	3
	Xerophyllum asphodeloides	0	1	1	3

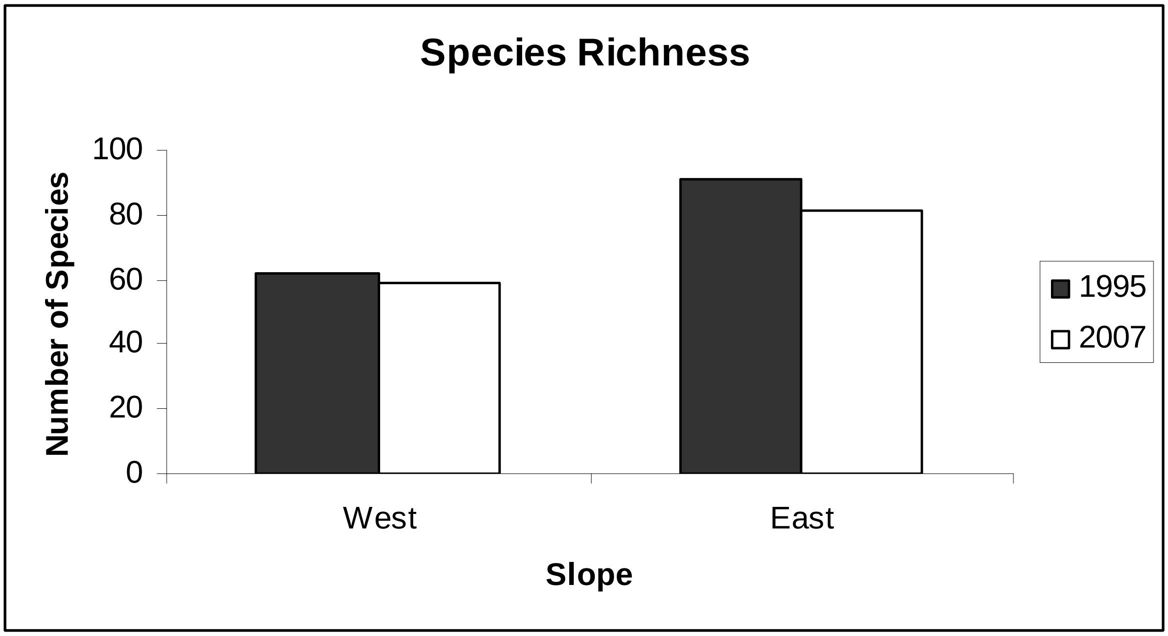

Figure 20: Species richness – illustrates species richness from 1995 and 2007 for two plots on the east facing slope (20-2-340 and 20-8-340) and two plots on the west facing slope (20-6-340 and 20-7-340).

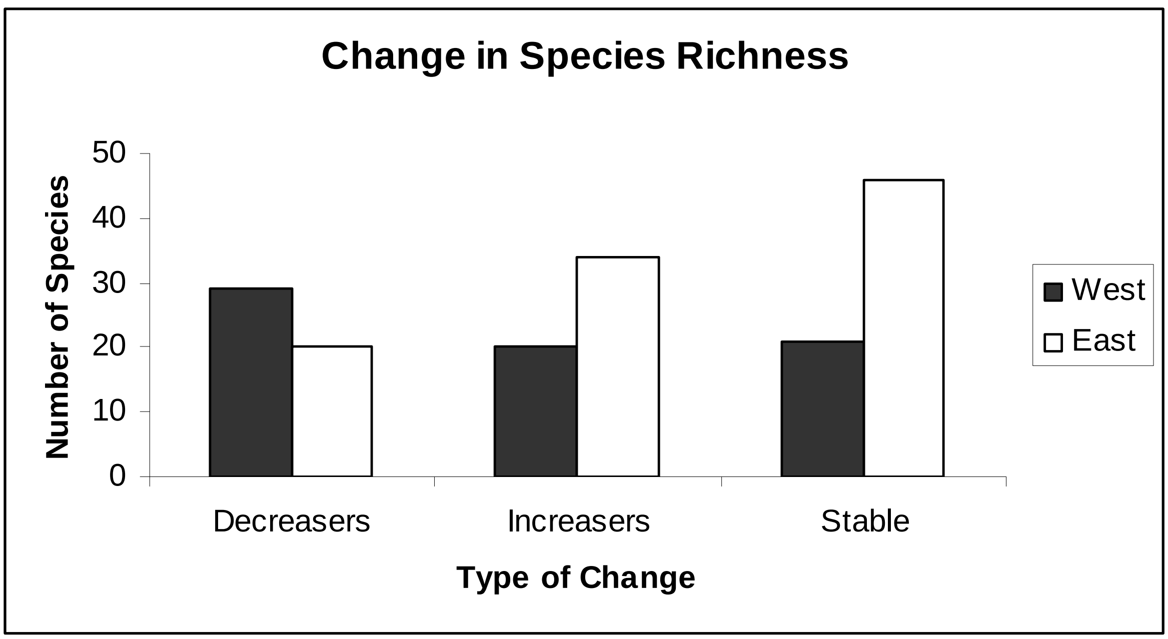

Figure 21: Change in species richness – shows the number of species that decreased, increased, or remained stable for two plots on the east facing slope (20-2-340 and 20-8-340) and two plots on the west facing slope (20-6-340 and 20-7-340).

Discussion

Fire:

Since the USFS began burning Buck Creek in 1995, five of the six resampled plots have been burned three times with an average interval of four years. The use of fire for maintaining serpentine sites is widespread in both the eastern and western United States as well as internationally (Alexander et al. 2006). According to Tyndall and Hull (1999), periodic fire is essential for preventing invasion of *Pinus* spp. and conversion of the barrens to pine forest.

In many systems fire is known to increase species richness; in Buck Creek, however, the species richness of the plots decreased by approximately 10% from 1995. Alexander et al. (2006) indicate that the soil infertility of the barren may have contributed this reduction in species because species from the matrix forest would not recruit as well after a fire as species native to the barrens. Because the goal of the USFS burning regime is to maintain the unique flora of the barren by reducing the density of canopy species and thereby increasing the population of rare species, reduced species richness is not only expected, but perhaps desirable because complete removal of some secure canopy species may facilitate the growth of rare herb layer species. However, Park (1990) explains that some serpentine shrubs are more susceptible to mortality after a fire event. Therefore, the intensity and frequency of fires must be controlled in order to moderate the number of species lost.

Soil:

Maintaining soil infertility is essential for preserving serpentine vegetation. As mentioned above, fire is often correlated with increasing species richness of an area due to lack of competition. It is the infertility of serpentine soil that prevents species from the forest matrix from invading the barrens.

According to Hall (1994), the long-term effects of prescribed fire on soil are not well known. Although the reduced levels of organic matter seen in this study are expected due to burning of the litter layer. This reduction of organic matter may affect the nutrient and drainage capacity of the soil (Hall 1994). Repeated soil testing may be necessary to ensure stability of soil conditions throughout the fire management period.

My data show that the low calcium to magnesium ratio desired for serpentine sites has been preserved in the plots via a reduction in calcium. However, the high magnesium levels have been mitigated slightly. Brooks (1987) explains that while a deficiency of calcium and toxic level of magnesium each play their own role in serpentine infertility, it is the ratio of calcium to magnesium that is considered most crucial for serpentine vegetation to thrive. In this regard the state of calcium and magnesium in Buck Creek is satisfactory.

<u>Woody Species Taller than Breast Height (1.4m):</u>

There are very few rare woody species in Buck Creek. Many of the woody species which are secure in the state of North Carolina are considered problematic to the preservation of the rare flora at the site. The species which have been specifically targeted for removal include, *Pinus rigida*, *Tsuga canadensis*, *Acer rubrum* var. *rubrum*, and *Quercus alba*. Mansberg and Wentworth (1984) showed that these species had higher importance values within the barrens than in the matrix forest. Targeted slashing and subsequent burning has effectively reduced the number of individuals of these species within the plots. Removal of *T. canadensis* will help maintain fire intensity during burnings because the trees tend to hold moisture in the soil at their bases. *P. rigida* was targeted for slashing because of its over abundance in the area. The reduction of *A. rubrum* and *Q. alba* will mitigate their large contribution to the litter layer which may ameliorate the harsh soil conditions in Buck Creek.

The data show that larger individuals of targeted tree species were reduced more than smaller individuals. This is due primarily to slashing and the desire of the USFS to limit the amount of litter accumulation on the ground. Arabas (2000) implies and Barton and Wallerstein (1997) have shown that litter from a serpentine canopy which is closing in can mitigate the soil infertility at the stand level. While most large individuals of targeted tree species were reduced, *Amelanchier arborea* showed a slight increase. While the persistence of one individual is not significant, it is important to note that slashing may need to target smaller individuals which may survive low intensity fire and persist between fire intervals.

<u>Intensive modules</u>:

The overall stability of some species regarding their presence within the intensive modules is provided by the disappearance of those species from one module combined with their appearance in another. The dynamic persistence of some species renders the sampling method used in this study inadequate for comprehensive analysis. Safford and Harrison (2004) examined pre and post-fire presence of exotic versus native species on serpentine using belt transects. Such a sampling system may be better suited for study of species which appear stable within the Buck Creek site but which move in response to fire events.

Rare species which are well adapted to serpentine and highly present within the Buck Creek plots (*Hexastylis arifolia* var. *ruthii*, *Packera plattensis*, and *Thalictrum macrostylum*) remained stable with regard to presence throughout the intensive modules. These rare species, which are have been noted for ecotypic differentiation within the Buck Creek site, are well established in the area and tolerant to fire events; they have therefore remained stable through the prescribed burning (Brooks 1987).

Secure species, however, which were also highly present in 1995 (*Vaccinium stamineum*, *Smilax glauca*, and *Pinus rigida*) were reduced in 2007. For *P. rigida* this is most likely due to targeted slashing. *V. stamineum*, is known to be fire tolerant and is often found in open areas with *P. rigida* (Hill 2002). It may be the serpentine soil that limits recruitment of this species after fire: Buck Creek's soil has a high pH for the state of North Carolina (average ~6.8) and *V. stamineum* is often found on acidic soil. Moreover, the high magnesium values of Buck Creek's soil are not optimal for growth of *V. stamineum* (Hill 2002).

The reduction of *S. glauca*, however, is more puzzling. This species is well suited for serpentine soil and fire-tolerant, yet it still showed significant reduction (loss from 17% of the 1995 plots). Hodgkin (1958) highlights the sensitivity of *S. glauca* to changes in pH; it is therefore possible that the slight increase in the pH of the soil in the plots has inhibited recruitment of *S. glauca* after fire events.

Overall, targeted slashing seems to have caused more species to experience large reductions than large increases. However, occurrence of increase or decrease is not restricted to species which are highly present or to those which are highly restricted within the plots. It is therefore important to understand that species which are restricted within the area may not increase after fire events regardless of decreased competition. The species which were present in 20-30% and 30-40% of the intensive modules in 2007 make up both the list of species which increased the most and the list of species which decreased the most since 1995. Therefore the species which are present in less than half of the intensive module have proved to be the most dynamic after the introduction of fire. Species which were present in more than half of the intensive module still exhibit change but only within 10% of the 1995 data (with the exception of *P. rigida* which was heavily targeted for slashing).

Just as with the secure species, the rare species within the plots demonstrated both increase and decrease regarding frequency of occurrence in intensive modules. Slightly less than half of the endangered species within the plots in 1995 decreased in presence. One of these species, *Gentianopsis crinita*, was completely lost from the plots. The remaining endangered species increased or remained unchanged in presence. *Poa saltuensis* and *Sporobolus heterolepis* are the two endangered species which increased the most. Both species are grasses which are at the southeastern periphery of their ranges (NatureServe). The moderate increase in *P. saltuensis* is probably due to its suitability for the site: it is reported to grow in both open and shady areas on rocky terrain and is tolerant of both wet and dry conditions (Schuyler 1990).

For *S. heterolepis*, however, this increase is lower than expected. Dix and Butler (1954) observed that a spring wild fire led to a 30 fold increase in *S. heterolepis* in a thinsoil prairie in Wisconsin, and Glen-Lewin et al. (1990) support the claim that spring fires are correlated with *S. heterolepis* increase. Abrams (1988) has shown that the multiple-year interval between fires is ideal for *S. heterolepis*. Since fires in Buck Creek are conducted in April and in three to four year intervals it is odd to see such a small increase in the presence of this rare species.

Several rare species were reduced in the intensive modules. The three rare species that were reduced the most were *Elymus trachycaulus*, *Parnassia grandifolia*, and *Symphyotrichum leave*. *E. trachycaulus* is favored by summer or fall burns (Bailey and Anderson 1978) and Gucker (2005) illustrated that this species can recover well after low, moderate, and severe intensity fires. Spring is the active growing period for *E. trachycaulus* and thus a vulnerable time for the species. The reduction in presence of *E. trachycaulus* may be due to the timing of Buck Creek burns which occur in mid to late spring.

P. grandifolia is sensitive to hydrologic changes (NatureServe 2007). In 1995 it was reported in two plots one straddled a small stream the other was slightly upslope from the stream. The drought conditions during the sampling which rendered the stream bed almost completely dry are the most likely reason for the reduced presence of this species in the intensive modules.

S. laeve is fire adapted and sprouts from the rhizome after fire events. Sullivan (1992) explains that there are conflicting reports in the literature concerning the response of this species to fire. Some studies list this species as a “decreaser;” others find that flowering is inhibited post-fire; still others state that flowering was stimulated post-fire (Sullivan 1992). The dry conditions in Buck Creek, particularly in during the drought in summer of 2007 may have contributed to this species’ reduced presence within the intensive modules.

The trends in change in species richness differed greatly for the east and west facing slopes. The species lists on the two slopes are similar but not identical. It is possible that the east facing slope has more increased species because it also has more drought tolerant and fire tolerant species. In terms of non-vegetational characteristics other than aspect, the only significant difference in the two slopes is a beetle kill which has affected the west facing slope but not the east. To adequately investigate this trend requires further data collection.

Conclusion

Overall, this study shows that the USFS burning regime in place at Buck Creek has effectively reduced the density of canopy species, increased the number of individuals of rare herb-layer species, and maintained the soil conditions which are essential for preserving the unique flora of the area.

The slashing treatment has ensured the removal of large canopy individuals, but has missed smaller individuals, which may survive low-intensity fires. Regarding rare species, the desired increase in abundance was at least partly achieved. The data demonstrate the stable presence of well-established rare species, but only moderate increases or decrease in the presence of those rare species that are not as well established. Because of the variability of serpentine derived soils, the results of this study are only applicable to the Buck Creek. However, these results will form the basis for further research and could perhaps be expanded and compared with data from other sites (e.g. Georgia and Virginia serpentine barrens).

Acknowledgements

This thesis would not have been possible without the help of the following individuals: My advisor Dr. Robert Peet, who allowed me to create my own project and read my final draft at 2:00 a.m.; my graduate student mentor, Lee Anne Jacobs, and three undergraduate field assistants, Grayson Privette, Sara Snow, and Amanda Liggin, who all braved cold weather, hot weather, snakes, and *Smilax* spp. to collect data; USFS Forest Botanical Specialist, Gary Kauffman, who graciously traveled from Asheville to help establish and resample the plots; Dr. Alan Weakley, who helped identify many plant samples and first introduced me to Buck Creek; Forbes Boyle who provided Carolina Vegetation Survey gear, shook soil samples, is an all-around helpful guy; and my husband, Jim, the best field assistant anyone could ask for.

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Appendices:

Appendix 1: Species List - The table below lists the species found in the six plots by scientific name, common name, and NatureServe rarity status (SH = possibly extirpated, 1 = endangered, 2 = threatened, 3 = vulnerable, 4 = apparently secure, 5 = secure, Exotic, NR = not ranked).

Plant Name	Common name	USDA Abbrev.	Global	State of NC
Symphyotrichum laeve var. laeve	Smooth Blue Aster	SYLAL	5	SH
Calamagrostis poteri ssp. porteri	Porter's Reedgrass	CAPOP	4	1
Carex echinata ssp. echinata	Star Sedge	CAECE	5	1
Elymus trachycaulus	Slender Wheatgrass	ELTR	5	1
Gentianopsis crinita	Greater Fringed Gentian	GECR	5	1
Muhlenbergia glomerata	Spiked Muhly	MUGL	5	1
Packera plattensis	Prairie Groundsel	PAPL	5	1
Poa saltuensis	Old Pasture Bluegrass	POSA	5	1
Ranunculus fascicularis	Early Buttercup	RAFA	5	1
Sporobolus heterolepis	Prairie Dropseed	SPHE	5	1
Symphyotrichum rhiannon	Rhiannon's Aster	SYRH	1	1
Cirsium muticum	Swamp Thistle	CIMU	5	2
Hexastylis arifolia var. ruthii	Ruth's Little Brown Jug	HEARR	5	2
Oenothera perennis	Little Evening-Primrose	OEPE	5	2
Parnassia grandifolia	Largeleaf Grass of Parnassus	PAGR	3	2
Polygala paucifolia	Gaywings	POPA	5	2
Spiraea alba var. latifolia	White Meadowsweet	SPALL	5	2
Stenanthium gramineum var. micranthum	Eastern Featherbells	STGRM	4	2
Symphyotrichum laeve var. concinnum	Smooth Blue Aster	SYLAC	5	2
Thalictrum macrostylum	Piedmont Meadow-Rue	THMA	3	2
Viola appalachiensis	Appalachian Blue Violet	VIAP	3	2
Amelanchier laevis	Allegheny Serviceberry	AMLA	4	3
Castilleja coccinea	Scarlet Indian Paintbrush	CACO	5	3
Gaylussacia ursina	Bear Huckleberry	GAUR	4	3
Hieracium scabrum	Rough Hawkweed	HISC	5	3
Houstonia serpyllifolia	Thymeleaf Bluet	HOSE	4	3
Physalis heterophylla	Clammy Groundcherry	PHHE	5	3
Rubus canadensis	Smooth Blackberry	RUCA	5	3
Sanguisorba canadensis	Canadian Burnet	SACA	5	3
Solidago curtisii	Curtis' Goldenrod	SOCU	4	3
Symphyotrichum phlogifolium	Late Purple Aster	SYPH	5	3
Symphyotrichum prenanthoides	Crooked Stem Aster	SYPR	5	3
Xerophyllum asphodeloides	Eastern Turkeybeard	XEAS	4	3
Andropogon gerardii	Big Blue Stem	ANGE	5	4
Bartonia virginica	Yellow Screwstem	BAVI	5	4
Carex rosea	Rosy Sedge	CARO	5	4
Dichanthelium clandestinum	Deertongue	DICL	5	4
Dichanthelium depauperatum	Starved Panicgrass	DIDE	5	4
Dichanthelium villosissimum var. villosissimum	Whitehair Rosette Grass	DIVIV	5	4
Gaultheria procumbens	Eastern Teaberry	GAPR	5	4

Hieracium paniculatum	Allegheny Hawkweed	HIPA	5	4
Lyonia ligustrina var. ligustrina	Maleberry	LYLIL	5	4
Oxypolis rigidior	Stiff Cowbane	OXRI	5	4
Phlox carolina	Thickleaf Phlox	PHCA	5	4
Phlox latifolia	Wideflower Phlox	PHLA	5	4
Physocarpus opulifolius var. opulifolius	Ninebark	PHOPO	5	4
Pinus rigida	Pitch Pine	PIRI	5	4
Scleria pauciflora	Fewflower Nutrush	SCPA	5	4
Vaccinium corymbosum	Highbush Blueberry	VACO	5	4
Vaccinium erythrocarpum	Southern Mountain Cranberry	VAER	5	4
Vaccinium simulatum	Mountain Highbush Blueberry	VASI	5	4
Viburnum nudum var. cassinoides	Withe Rod	VINUC	5	4
Viola pedata	Birdfoot Violet	VIPE	5	4
Viola sagittata	Arrowleaf Violet	VISA	5	4
Acer rubrum var. rubrum	Red Maple	ACRUR	5	5
Agrostis perennans	Upland Bentgrass	AGPE	5	5
Amelanchier arborea	Downy Serviceberry	AMAR	5	5
Andropogon ternarius	Splitbeard Bluestem	ANTE	5	5
Andropogon virginicus var. virginicus	Broomsedge Bluestem	ANVIV	5	5
Angelica venenosa	Hairy Angelica	ANVE	5	5
Asclepias verticillata	Whorled Milkweed	ASVE	5	5
Asplenium platyneuron var. platyneuron	Ebony Spleenwort	ASPLP	5	5
Aureolaria virginica	Downy Yellow False Foxglove	AUVI	5	5
Betula lenta	Sweet Birch	BELE	5	5
Campanula divaricata	Small Bonny Bellflower	CADI	5	5
Carex pensylvanica	Pensylvania sedge	CAPE	5	5
Ceanothus americanus	New Jersey Tea	CEAM	5	5
Chamaelirium luteum	Fairywand	CHLU	5	5
Chimaphila maculata	Striped Prince's Pine	CHMA	5	5
Coreopsis major	Greater Tickseed	COMA	5	5
Cypripedium acaule	Pink Lady's Slipper	CYAC	5	5
Danthonia spicata	Poverty Oatgrass	DASP	5	5
Dichanthelium commutatum	Variable Panicgrass	DICO	5	5
Dichanthelium laxiflorum	Openflower Rosette Grass	DILA	5	5
Dichanthelium sphaerocarpon	Roundseed Panicgrass	DISP	5	5
Diospyros virginiana	Common Persimmon	DIVI	5	5
Dryopteris marginalis	Marginal Woodfern	DRMA	5	5
Epigaea repens	Trailing Arbutus	EPRE	5	5
Euphorbia corollata	Flowering Spurge	EUCO	5	5
Gaylussacia baccata	Black Huckleberry	GABA	5	5
Goodyera pubescens	Downy Rattlesnake Plantain	GOPU	5	5
Helianthus atrorubens	Purpledisk Sunflower	HEAT	5	5
Helianthus microcephalus	Small Woodland Sunflower	HEMI	5	5
Houstonia purpurea var. purpurea	Venus' Pride	HOPUP	5	5
Hypoxis hirsuta	Eastern Yellow Star Grass	HYHI	5	5
Ilex montana	Mountain Holly	ILMO	5	5
Ilex opaca var. opaca	American Holly	ILOP	5	5
Kalmia latifolia	Mountain Laurel	KALA	5	5

Liriodendron tulipifera	Tuliptree	LITU	5	5
Lobelia puberula	Downy Lobelia	LOPU	5	5
Lysimachia quadrifolia	Whorled Yellow Loosestrife	LYQU	5	5
Magnolia acuminata	Cucumber Tree	MAAC	5	5
Magnolia fraseri	Mountain Magnolia	MAFR	5	5
Mitchella repens	Partridge Berry	MIRE	5	5
Nyssa sylvatica	Blackgum	NYSY	5	5
Oenothera fruticosa	Narrowleaf Evening-Primrose	OEFR	5	5
Oenothera fruticosa ssp. glauca	Narrowleaf Evening-Primrose	OEFRG	5	5
Oxydendrum arboreum	Sourwood	OXAR	5	5
Packera anonyma	Small's Ragwort	PAAN	5	5
Pinus strobus	Eastern White Pine	PIST	5	5
Polypodium virginianum	Rock Polypody	POVI	5	5
Polystichum acrostichoides var. acrostichoides	Christmas Fern	POACA	5	5
Porteranthus trifoliatus	Bowman's Root	POTR	4	5
Prenanthes serpentaria	Cankerweed	PRSE	5	5
Prunella vulgaris	Common Selfheal	PRVU	5	5
Prunus serotina	Black Cherry	PRSE	5	5
Quercus alba	White Oak	QUAL	5	5
Quercus coccinea var. coccinea	Scarlet Oak	QUCOC	5	5
Quercus rubra	Northern Red Oak	QURU	5	5
Quercus velutina	Black Oak	QUVE	5	5
Rhododendron maximum	Great Laurel	RHMA	5	5
Rhododendron viscosum	Swamp Azalea	RHVI	5	5
Rudbeckia hirta	Black-Eyed Susan	RUHI	5	5
Sabatia angularis	Rosepink	SAAN	5	5
Sassafras albidum	Sassafras	SAAL	5	5
Schizachyrium scoparium	Little Bluestem	SCSC	5	5
Sericocarpus asteroides	Toothed Whitetip Aster	SCAS	5	5
Smilax glauca	Cat Greenbrier	SMGL	5	5
Smilax herbacea	Smooth Carrionflower	SMHE	5	5
Smilax rotundifolia	Roundleaf Greenbrier	SMRO	5	5
Solidago bicolor	White Goldenrod	SOBI	5	5
Solidago nemoralis var. nemoralis	Gray Goldenrod	SONEN	5	5
Sorghastrum nutans	Indian Grass	SONU	5	5
Stellaria pubera	Star Chickweed	STPU	5	5
Stylosanthes biflora	Sidebeak Pencilflower	STBI	5	5
Symphyotrichum undulatum	Heartleaf Panicled Aster	SYUN	5	5
Thaspium trifoliatum	Purple Meadowparsnip	THTR	5	5
Tsuga canadensis	Eastern Hemlock	TSCA	4	5
Vaccinium pallidum	Blue Ridge Blueberry	VAPA	5	5
Vaccinium stamineum	Deerberry	VAST	5	5
Zizia trifoliata	Heartleaf Alexanders	ZIAP	5	5
Festuca ovina	Sheep Fescue	FEOV		Exotic
Andropogon gyrans var. gyrans	Elliott's Bluestem	ANGYG	5	NR
Aristida purpurascens var. purpurascens	Arrowfeather Threeawn	ARPUP	5	NR
Deschampsia caespitosa	Tufted Hairgrass	DECA	5	NR
Deschampsia flexuosa var. flexuosa	Crinkled Hairgrass	DEFLF	5	NR

Dichanthelium aciculare	Needleleaf Rosette Grass	DIAC	4	NR
Dichanthelium dichotomum var. dichotomum	Cypress Panicgrass	DIDID	5	NR
Erechtites hieraciifolia var. hieraciifolia	American Burnweed	ERHIH	5	NR
Eubotrys recurva	Fetter-Bush	EURE	NR	NR
Festuca subverticillata	Nodding Fescue	FESU	5	NR
Lactuca floridana var. villosa	Woodland Lettuce	LAFLV	5	NR
Panicum virgatum var. virgatum	Switchgrass	PAVIV	5	NR
Polytrichum commune	Polytrichum Moss	POCO	5	NR
Pteridium aquilinum var. latiusculum	Western Bracken Fern	PTAQL	5	NR
Silene virginica var. virginica	Fire Pink	SIVI	5	NR
Viola cucullata	Marsh Blue Violet	VICU	4	NR
Viola sororia	Common Blue Violet	VISO	5	NR

Appendix 2: Species Change - The tables below show the change in the frequency of occurrence of each species within the intensive modules. Rare species (those with a rarity status ≤ 3) are indicated with asterisks (*** = 1, ** = 2, * = 3). Species are listed in order of decreasing change. *Sorghastrum nutans*, *Tsuga canadensis*, and *Oenothera fruticosa* experienced the greatest decrease in presence. *Dechampsia caespitosa*, *Stenanthium gramineum* var. *micranthum*, and *Symphyotrichum rhiannon* experienced the greatest increase in presence.

Decreased			
Species Abbrev	Change	Species Abbrev	Change
SONU	-13	SYLAL***	-2
TSCA	-8	VICU	-2
OEFR	-7	ACRUR	-1
PAAN	-6	ANVIV	-1
PIRI	-6	ANVE	-1
VASI	-6	AUVI	-1
BELE	-5	CAECE***	-1
CADI	-5	DIDID	-1
PRVU	-5	GECR***	-1
DEFLF	-4	GOPU	-1
DIVI	-4	HEAT	-1
PAGR**	-4	ILMO	-1
PHOPO	-4	ILOP	-1
POPA**	-4	LITU	-1
POACA	-4	LOPU	-1
QUAL	-4	MAAC	-1
QUCOC	-4	MUGL***	-1
QURU	-4	NYSY	-1
SMGL	-4	POVI	-1
SOBI	-4	POCO	-1
SYLAC**	-4	QUVE	-1
VAPA	-4	RHMA	-1
VAST	-4	SCSC	-1
CARO	-3	SOCU*	-1
ELTR***	-3	SONEN	-1
ERHIH	-3	SPALL**	-1
EUCO	-3	STPU	-1
FEOV	-3	VACO	-1
FESU	-3	VAER	-1
PHCA	-3	VIPE	-1
PRSE	-3	VISO	-1
SAAL	-3		
VINUC	-3		
VISA	-3		
ANTE	-2		
ASVE	-2		
CHLU	-2		
EPRE	-2		
HOSE*	-2		
OXAR	-2		
OXRI	-2		
POTR	-2		
SACA*	-2		
SMRO	-2		

No Change	
Species Abbrev	Change
AGPE	0
ANGYG	0
ARPUP	0
BAVI	0
CAPE	0
CEAM	0
CIMU**	0
CYAC	0
DASP	0
DIAC	0
DIDE	0
DILA	0
DISP	0
DIVIV	0
DRMA	0
HEMI	0
HEARR**	0
HOPUP	0
MAFR	0
PAPL***	0
PHLA	0
PHHE*	0
PIST	0
PRSE	0
RHVI	0
SAAN	0
SMHE	0
STBI	0
THMA**	0
THTR	0

Increased	
Species Abbrev	Change
DECA	6
STGRM**	5
SYRH***	5
RUCA*	4
DICL	3
HIPA	3
SYPR*	3
SYUN	3
CACO*	2
DICO	2
MIRE	2
PAVIV	2
POSA***	2
SIVI	2
SPHE***	2
AMAR	1
AMLA*	1
ANGE	1
ASPLP	1
CAPOP*	1
CHMA	1
COMA	1
EURE	1
GAPR	1
GABA	1
GAUR*	1
HISC*	1
HYHI	1
KALA	1
LAFLV	1
LYLIL	1
LYQU	1
OEFRG	1
OEPE**	1
PTAQL	1
RAFA***	1
RUHI	1
SCPA	1
SCAS	1
SYPH*	1
VIAP**	1
XEAS*	1
ZIAP	1

Appendix 3: Photographs - Below are three photographs from the reestablishment trip (March 200):

Figure 22: Plot 20-08-340 located on the slope about 100 meters south of the powerline right-of-way

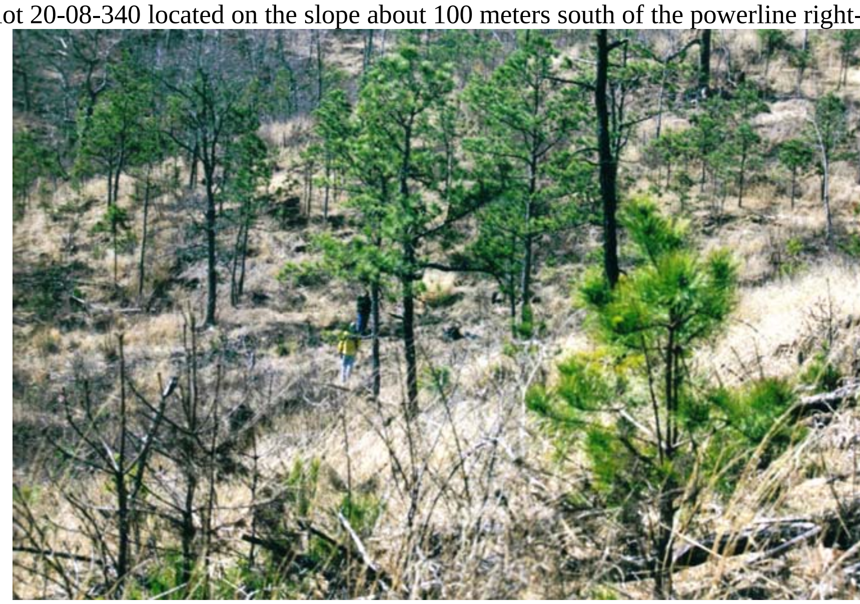

Figure 23: Plot 20-2-340 located due south of first plot; follows small stream.

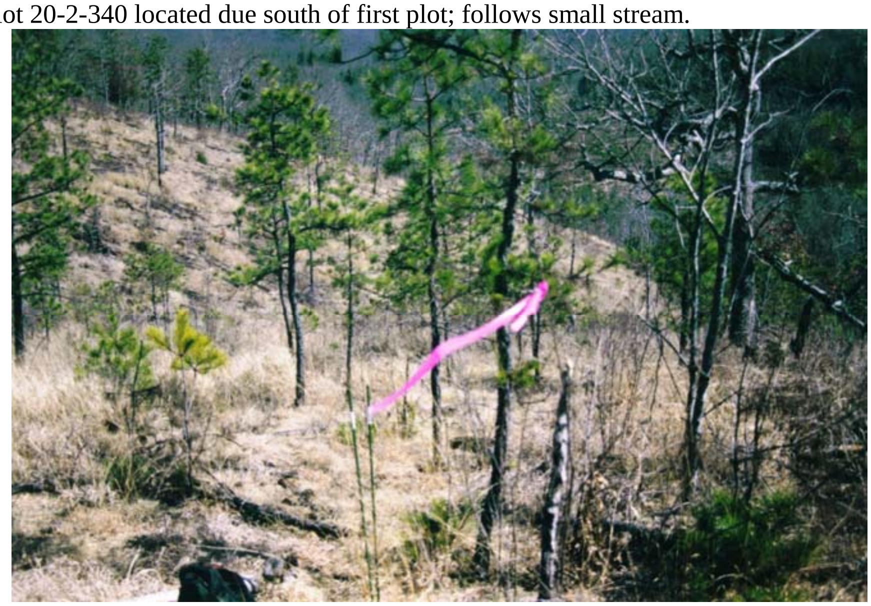

Figure 24: Plot 20-4-341 - View down slope toward the second plot.

Figure 25: View of plot 20-2-340 (August 2007).

Figure 26: View from plot 20-8-340 to plot 20-4-341.

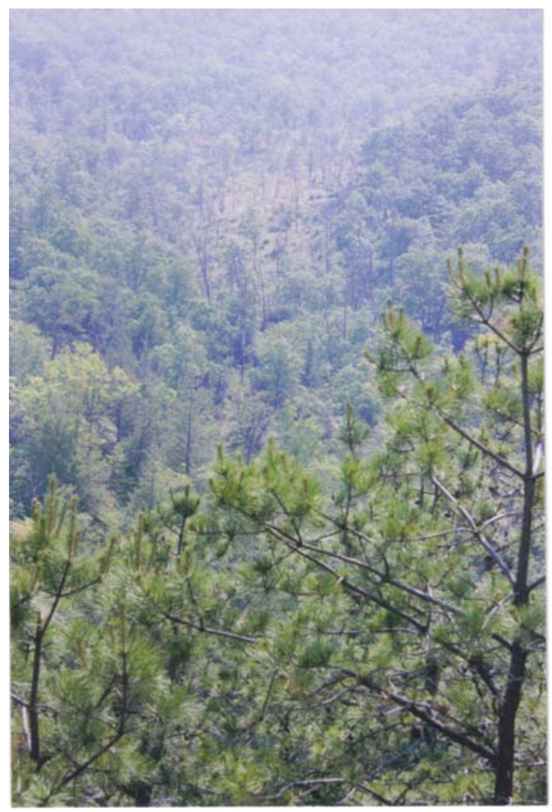

Figure 27: View of the east facing slope from plot 20-6-340.