Site preparation burning to improve southern Appalachian pine–hardwood stands: vegetation composition and diversity of 13-year-old stands[1]

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Stand restoration of low-quality, mixed pine-hardwood ecosystems containing a *Kalmia latifolia* L. dominated understory, through cutting, burning, and planting of *Pinus strobus* L., is common on xeric southern Appalachian forest sites. We examined the effects of this treatment on early vegetation composition and diversity. Four 13-year-old stands were examined. Two of the four stands were mechanically released at age 6. Density and basal area were estimated for understory and overstory components, and density and percent cover for the herb component. Species diversity (Shannon-Wiener index) was estimated and comparisons were made between layers, sites, and treatments (release vs. nonrelease). Diversity estimates were 3.19, 1.74, and 2.45 for the herb, shrub, and overstory layers, respectively, across all sites and treatments. For perspective, comparisons were made with an untreated reference stand that was typical of stands receiving site preparation burning in the southern Appalachians. Overstory and herb diversity estimates were significantly lower for the reference stand than for the 13-year-old stands.

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La conversion de peuplements mixtes de pins et de feuillus de faible qualité contenant un sous-étage dominé par *Kalmia latifolia* L., par la coupe, le brûlage et la plantation de *Pinus strobus* L., est une prescription commune sur les stations forestières xériques du sud des Appalaches. L'étude présentée porte sur les effets initiaux de cette pratique sur la composition et la diversité de la végétation. Quatre peuplements de 13 ans ont été étudiés dont deux avaient été dégagés mécaniquement à l'âge de 6 ans. La densité et la surface terrière ont été évaluées pour le couvert et le sous-étage, alors que la densité de même que le pourcentage de couverture ont été utilisés pour la strate herbacée. La diversité spécifique (mesurée par l'index de Shannon-Wiener) a été estimée et des comparaisons ont été effectuées entre les strates, les sites et les traitements (dégagés ou non). Pour l'ensemble des stations et des traitements, les estimés de diversité étaient respectivement de 3,19, 1,74 et 2,45 pour les strates herbacées, arbustives et le couvert. À titre de référence, des comparaisons ont été faites avec un peuplement témoin non traité, typique de ceux retenus pour la preparation de terrain à l'aide du brûlage dans le sud des Appalaches. Les estimés de la diversité du couvert et de la strate herbacée étaient significativement inférieurs pour le témoin en comparaison avec les mêmes strates dans les peuplements de 13 ans.

[Traduit par la rédaction]

Introduction

An important component of southern Appalachian forest ecosystems is the xeric, pine, or mixed oak-pine forest type. In recent years, the pine component of this forest type has been substantially reduced by drought-induced southern pine beetle (*Dendroctonus frontalis* Zimmerman) attacks (Smith 1991). As a result, extensive areas of poorly stocked stands with a dense shrub layer dominated by *Kalmia latifolia* L. now occupy these sites. Chainsaw felling, burning, and planting of eastern white pine (*Pinus strobus* L.) is currently prescribed to convert these low-quality, shrub-dominated stands to more productive mixed-hardwood and *P. strobus* stands. A major objective of the treatment is to reduce *K. latifolia* competition with the planted seedlings (see Swift et al. 1993). The effect of this treatment on vegetation diversity is unknown. Recent emphasis on the maintenance of biological diversity in forested ecosystems (Salwasser 1990) has prompted managers to evaluate the impacts of many alternative management techniques. Practices intended to improve timber production may also substantially alter biological diversity relative to undisturbed stands. Quantifying effects on biological diversity requires both short- and long-term assessments of community composition, structure, and function.

The objectives of our study were to evaluate the effects of felling and burning, followed by an early mechanical release, on vegetation recovery and overall plant species diversity approximately 13 years after treatment. To put our results in perspective, we compared results from this study on the 13-year-old stand (Blazed Creek) with a reference ecosystem (see Swift et al. 1993) representing pretreatment conditions typical of the stands selected for this silvicultural treatment. In addition, qualitative comparisons were made with estimates of diversity and species evenness determined for the overstory of an undisturbed mixed-hardwood watershed (WS13) in the Coweeta Basin (see Parker and Swank 1982).

Methods

Site description

Both the Blazed Creek (BC) and reference study sites are in the Blue Ridge physiographic province of the southern Appalachians 35°N, 83°W). They are on the Wayah Ranger District of the Nantahala National Forest, approximately 10 km north of Franklin, N.C. The reference sites are from a related study examining ecosystem responses to cutting and burning (described in Swift et al. 1993). Pretreatment vegetative composition on these sites was characteristic of pine-hardwood ecosystems in the southern Appalachians (Swift et al. 1993). No timber harvests had occurred in the last 20 years on either the reference or BC sites.

Annual precipitation is approximately 1700 mm and is evenly distributed throughout the year. Mean annual temperature is approximately 14°C. The soils are primarily of the Evard–Cowee Complex, which consists of fine-loamy, mixed, mesic, Typic Hapludults.

In the BC watershed, four sites ranging from 8 to 10 ha were selected for this study. Elevation (730 to 975 m) and aspect (approximately southeast) are similar on all sites. The reference study con-

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sisted of three sites, approximately 5.25 ha each, ranging in elevation from 765 to 1040 m. All reference study sites had approximate southwest aspects.

Treatments

At BC, most woody vegetation was clear-felled and burned in 1976-1977 and planted in 1977. Overstory cutting over much of the area was incomplete, resulting in a residual overstory of pitch pine (*Pinus rigida* Mill.), shortleaf pine (*Pinus echinata* Mill.), and Virginia pine (*Pinus virginiana* Mill.). Estimates of density and basal area for this component were 5 stems/ha and 0.5 m^2/ha, respectively.

Pinus strobus was planted on a 6 x 6 m spacing the first winter after site preparation. At age 6, two of the sties were released mechanically. All woody vegetation within 2 m of each planted P. *strobus* was cut to ground level.

Plot selection and layout

Four 15 x 33 m plots were established at each site. The long plot boundary was oriented along the contour, and plots were systematically distributed at approximately 40-m intervals upslope to ensure representative sampling of the site. The overstory was sampled on the entire area of the 15 x 33 m plots. Each contained four randomly located 5 x 5 m plots for sampling the shrub layer and four 1-m^2 plots located randomly outside the 5 x 5 m plots for the herb layer.

In the reference study, each site contained nine 15 x 33 m plots systematically arranged to ensure a representative sample. Each large plot contained one randomly located 3 x 3 m plot for shrub sampling and four randomly located 1-m^2 plots to sample the herb layer.

Although the sampling intensity was different for the reference stands relative to BC, species area curves for both sites indicated that the sampling intensities were sufficient for a representative sample of each layer (i.e., relationships between species number and sampling intensity were asymptotic).

Vegetation measurements

With the exception of *K. latifolia* and *Rhododendron maximum* L., the overstory sampling on the BC sites included all woody stems >2.54 cm in diameter at breast height (DBH) 1.4 m above ground. The diameters of all stems in this class were measured and each identified to species. Shrub-layer sampling included woody plants 2.54 cm DBH or smaller to a minimum of 0.25 cm basal diameter, as well as all *K. latifolia* and *R. maximum.* Exceptions in shrub sampling included *Pyrularia pubera* Michx., *Vaccinium* spp., and *Gaylussacia* spp. which were inventoried in the herb layer. Individual stems were counted on the 1-m^2 plots, and percent cover was estimated by eye. All woody species nomenclature follows Little (1979). All herb nomenclature follows Radford et al. (1968).

In the reference study the overstory was defined as all woody stems >2.5 cm DBH. The shrub layer included *K. latifolia, R. maximum,* and all other woody stems <2.5 cm DBH. The herb layer was sampled in the same manner as the BC site.

Statistical analysis

A folded-form F-statistic was used to test for homogeneous variances (SAS Institute Inc. 1987). When variances were equal, significant differences between means were evaluated with parametric Student's t-tests. When variances were not homogeneous, an approximate t-test and Satterthwaite's method for computing degrees of freedom were used (SAS Institute Inc. 1987). Relationships between variables were determined with Pearson correlation coefficients at the plot level ($n = 16$).

A diversity index was calculated with the Shannon-Wiener formula (Magurran 1988):

$$H' = -\sum p_i \ln p_i$$

where H' is index of diversity and p_i is the probability of occurrence of the ith species. Number of stems per hectare was the abundance measure for all layers. Estimates of evenness were determined with the equation (Magurran 1988)

$$E' = \frac{H'}{H_{\max}}$$

where

E' is the estimate of evenness of species distribution

H' is the estimate of species diversity

$H_{\max}$ is the maximum level of diversity possible within a given population and equals ln(number of species)

The significance of differences in species diversity between populations was evaluated with a technique developed by Hutcheson (1970). The technique is based on the known distributional properties of the diversity estimates. Comparisons were made on the basis of 95% confidence intervals derived from this technique.

Quantifying species diversity, as we have done, requires two important assumptions: *(i)* all individuals assigned to a specific class are equal and (ii) all species or classes are equally different (Peet 1974). These assumptions are often false. The first assumption ignores differences due to genetic heterogeneity, and the second ignores the varying functional attributes of the classes or species (e.g., nitrogen fixers, evergreens, etc.). Even though these assumptions may be violated, the indices can indicate subtle differences in composition, structure, and function between communities (Taylor 1978), which, as Magurran (1988) points out, is a critical attribute of any index of diversity if one is examining the impacts of environmental stresses on community diversity.

Results and discussion

Species composition

In Table 1, overstory species at the BC site are ranked by density. Many species at BC are typical of early succession in this forest type in the southern Appalachians (Boring et al. 1988). For all BC sites, 75% of the density was accounted for by *Acer rubrum* L., *Quercus coccinea* Muenchh., *Quercus prinus* L., *Oxydendron arboreum* (L.) DC., *P. rigida*, and planted *P. strobus,* which alone accounted for 11% of the density and 41% of the basal area. *Quercus* spp. accounted for 39 and 21% of the density and basal area, respectively.

Yellow pines (subgenus *Diploxylon)* accounted for a significant proportion of overstory abundance. For example, *P. rigida* was the second most abundant species of pine, followed by *P. echinata,* and *P. virginiana. Pinus rigida*, alone, accounted for 15% of the basal area and 9% of the density. The significant yellow pine component was composed of the residual pine overstory and newly established individuals. These species are adapted to the dry and infertile conditions characteristic of these ecosystems (Knoepp and Swank 1993) and, hence, grow faster than hardwood species. After removing residual overstory *Pinus* from the data, mean DBH for yellow pines was still significantly larger ($p = 0.0001$) than that of overstory hardwood species. This difference implies that pines were early arrivals following site preparation and, because of their relatively high early growth rates, represent a substantial proportion of the overstory basal area. At BC, *P. rigida* was second in basal area to *P. strobus* in the overstory. Furthermore, basal area for residual yellow pine overstory was 0.5 m^2/ha compared with 0.7 m^2/ha for the yellow pine regeneration. However, as competition in the understory increases, few, if any, yellow pines will become established or move from the shrub to the overstory layer, primarily because of their shade intolerance but also because microsite requirements for seed germination are no longer being met.

Fire exclusion in the southern Appalachians has favored evergreen shrubs (Monk et al. 1985), and their dominance in

TABLE 1. Summary of overstory species (>2.54 cm DBH) at Blazed Creek

	Basal area (m^2/ ha)	Mean DBH (cm)	Stems/ha	Relative density	Relative basal area
Quercus coccinea	0.965	4.44	546	0.208	0.132
Oxydendron arhoreum	0.385	3.58	351	0.134	0.053
Acer rubrum	0.427	3.94	309	0.118	0.058
Pinus strobus	3.003	10.52	296	0.113	0.410
Pinus rigida	1.092	6.07	243	0.092	0.149
Quercus prinus	0.410	4.39	239	0.091	0.056
Carya spp.	0.162	3.71	136	0.052	0.022
Quercus falcata	0.126	3.99	94	0.036	0.017
Robinia pseudo-acacia	0.199	4.93	81	0.03 1	0.027
Quercus velutina	0.094	3.94	71	0.027	0.013
Nyssa sylvatica	0.060	3.23	68	0.026	0.008
Cornus florida	0.049	3.25	57	0.022	0.007
Quercus alba	0.036	3.51	35	0.014	0.005
Quercus stellata	0.022	3.35	24	0.009	0.003
Castanea pumila	0.133	3.12	16	0.006	0.007
Pinus echinata	0.054	5.94	15	0.006	0.007
Liriodendron tulipifera	0.018	4.50	10	0.004	0.002
Amelanchier arborea	0.008	3.15	10	0.004	0.001
Sassafras albidum	0.004	2.74	6	0.002	0.000
Castanea dentata	0.010	4.42	6	0.002	0.001
Rhus copallina	0.002	2.92	3	0.001	0.000
Pinus virginiana	0.019	9.14		0.001	0.003
Diospyrus virginiana	0.002	3.43		0.001	0.000
Tsuga canadensis	0.049	22.35		0.000	0.007
Total	7.33	4.98	2622		

NOTE: Species are in rank order of importance based upon density (stems/ha). Totals are on a per hectare basis.

the understory has a profound impact on recruitment of *Pinus* species (Clinton et al. 1993). For example, from 1971 to 1988, 98% of the *P. rigida* stand area in the Coweeta Basin was lost (Smith 1991). In Smith's (199 1) study, *P. rigida* regeneration was not present in large canopy openings of varying ages created by mortality of overstory *P. rigida*. This dramatic reduction in area is due in part to stress-induced insect outbreaks (Barden 1988) but also to the inability of *P. rigida* to reproduce in the absence of fire. The majority of wildfires that do occur in the southern Appalachians are caused by humans, but most (natural or human-caused) lack the intensity necessary to promote pine reproduction (Barden and Woods 1976). Only the most intense crown fires result in any appreciable pine reproduction (Barden and Woods 1976). Therefore, site preparation burning may be an important means of promoting pine regeneration.

The shrub layer was dominated by *K. latifolia,* which accounted for 67% of the basal area and 59% of the density in the shrub layer (Table 2). *Kalmia latifolia's* dominance illustrates its ability to recover from severe disturbance. Nevertheless, the data for BC indicate that site preparation burning reduced *K. latifolia* competition sufficiently for *P. strobus* and other species to become established and, subsequently, occupy the overstory. In spite of the dense *K. latijolia,* a total of 32 species were identified in the shrub layer (Tables 2 and 3). Many of these, including seven species of *Quercus,* were potential canopy species.

In the herb layer, the most frequently occurring species was *Smilax glauca* Walt., which ranked second in abundance to the ericad *Vaccinium vacillans* Torr. (Table 4). Other members of the family Ericaceae included *Gaylussacia urisina* (M.A. Curtis) T.&G. ex Gray, *Vaccinium staminium* L., *Epigaea repens* L., *Chimaphila maculata* (L.) Pursh, and *Gaultheria procumbens* L. Members of this family accounted for 27% of the density in the herb layer at BC (Table 4). Important nitrogen-fixing species included *Tephrosia virginiana* L., *Lespedeza repens* (L.) Bart., *Clitoria mariana* L., *Lespedeza hirta* (L.) Homemann, *Baptisia tinctoria* (L.) R. Br., and *Lespedeza intermedia (S.* Wats.) Britt. In all, 64 species were identified in the herb layer at BC (Table 3).

Influences of K. latifolia *on stand development*

Kalmia latifolia may be the most important competitor to regenerated hardwoods and planted *P. strobus* seedlings, and a major objective of burning is to reduce the vigor of *K. latifolia* sprouts. The effectiveness of felling and burning for reducing competition was examined by relating *K. latifolia* basal area to overstory characteristics. We found a significant positive relationship between mean overstory DBH and *K. latifolia* basal area ($r = 0.656$; $p = 0.006$; Fig. *la).* The mean DBH of *P. strobus (4.14* cm; Table 1) was significantly larger ($p = 0.0002$) than all other overstory stems combined and was strongly correlated with *K. latifolia* basal area ($r = 0.702$; $p = 0.002$; Fig. lb). All *Quercus* spp. combined exhibited a similar trend ($r = 0.734$; $p = 0.001$; Fig. Ic), but all overstory combined, excluding *P. strobus,* did not ($r = 0.103$; $p = 0.703$; Fig. 1*d*). Hence, this relationship was essentially driven by *Quercus* spp. and *P. strobus.*

We were concerned that the plot with the extremely high *K. latifolia* basal area (Figs. *la-lb,* 2, and 4) was largely responsible for the significant relationships observed; however, we had no rationale for removing this plot (i.e., the data were collected and analyzed correctly). We examined the influence of this plot by removing it, reanalyzing the data, and comparing relationships observed with and without the plot. With the exception of Fig. 1 *b,* all relationships using the

TABLE 2. Summary of woody understory species (0.25 cm basal diameter to 2.54 cm DBH) at Blazed Creek

Species	Basal area (m^2/ ha)	Mean DBH (cm)	Stems/ ha	Relative density	Relative basal area
Kalmia latifolia	6.284	1.70	21 525	0.586	0.669
Nyssa sylvatica	0.720	1.39	3 312	0.090	0.077
Calycanthus floridus	0.069	1.61	1 956	0.053	0.007
Acer rubrum	0.290	1.35	1 569	0.043	0.031
Quercus coccinea	0.280	1.35	1 525	0.033	0.030
Rhododendron maximum	0.242	1.35	1 181	0.032	0.026
Oxydendron arboreum	0.380	1.91	1113	0.030	0.040
Pinus rigida	0.279	1.85	700	0.019	0.030
Quercus prinus	0.140	1.45	663	0.018	0.015
Carya spp.	0.160	1.98	425	0.012	0.017
Quercus velutina	0.063	1.45	300	0.008	0.007
Cornus florida	0.130	2.11	263	0.007	0.014
Quercus alba	0.040	1.47	194	0.005	0.004
Rhus glabra	0.025	1.19	188	0.005	0.003
Amelanchier arborea	0.034	1.42	175	0.005	0.004
Sassafras albidum	0.037	1.57	156	0.004	0.004
Rhus copallina	0.023	1.19	150	0.004	0.002
Quercus falcata	0.050	1.91	138	0.004	0.005
Castanea pumila	0.026	1.60	119	0.003	0.003
Seedlings*	0.004	0.61	113	0.003	0.000
Castanea dentata	0.013	1.09	106	0.003	0.001
Ilex opaca	0.020	1.29	100	0.003	0.002
Liriodendron tulipifera	0.020	1.50	94	0.003	0.002
Quercus stellata	0.016	1.37	87	0.002	0.002
Robinia pseudo-acacia	0.024	1.75	81	0.002	0.003
Diospyrus virginiana	0.014	1.93	44	0.001	0.001
Prunus serotina	0.003	0.83	38	0.001	0.000
Pinus virginiana	0.000	0.51	19	0.001	0.000
Fagus grandifolia	0.004	1.45	19	0.000	0.000
Tsuga canadensis	0.000	0.33	19	0.000	0.000
Pinus strobus	0.000	0.38	13	0.000	0.000
Quercus rubra	0.003	1.65	13	0.000	0.000
Cornus alternafolia	0.002	1.40	13	0.000	0.000
Vitus aestivalis	0.002	1.27	13	0.000	0.000
Total	9.397	1.63	36 708		

NOTE: Species are in rank order of importance based upon density (stems/ha). Totals are on a per hectare basis.
*Includes a variety of species (<0.25 cm basal diameter), primarily of the genus *Quercus*.

data set without the plot were significant at least at $p < 0.10$, and the patterns (positive or negative correlation) remained the same as with the complete data set. Based on these results, we conclude that this plot represents the upper end of the *K. latifolia* basal area – overstory relationships.

The positive relationship between *K. latifolia* basal area and overstory DBH is counterintuitive. One possible explanation is that competition for available resources between *K. latifolia* and potential overstory trees was more important in earlier stages of succession. Once the overstory has emerged from the dense *K. latifolia* understory, competition that was between shrub and potential overstory trees may shift to competition for light and space between overstory trees. This phenomenon is reflected in Fig. 2, which shows that as *K. latifolia* basal area increases, overstory density decreases ($I = -0.526$; $p = 0.036$). Hence, *K. latifolia* competition may have decreased the survivorship of seedlings that would have eventually become overstory components. As noted earlier, overall mean diameter in the overstory increased ($r = 0.656$; $p = 0.006$; Fig. la) as *K. latifolia* basal area increased. This relationship may be due to less competition between overstory species as a result of the lower overstory density. Thus, the primary competitive effect of *K. latifolia* was to reduce the number of stems reaching the overstory.

Species diversity

Although significant differences in species diversity were observed between release treatments (e.g., release vs. nonrelease) for the overstory and herb layers, differences were not significant for the shrub layer (Table 3). This is likely due to the impact of *K. latifolia* on the diversity estimates. The distribution of species in this layer is heavily skewed toward *K. latifolia*, which is reflected in the low estimate of species evenness in Table 3 ($E' = 0.50$) and the impact this has upon diversity illustrated in Fig. 3.

The shrub layer was consistently low in species diversity owing primarily to the dominance of *K. latifolia*. Shrub diversity decreased significantly ($r = -0.562$; $p = 0.023$) as *K. latifolia* basal area increased (Fig. 4). The herb layer showed the highest estimates of diversity across treatments and for site totals ($H' = 3.19$; Table 3). The high diversity in this layer may be due to the clumped nature of the shrub layer, a phenomenon that had its greatest influence on herbs. Where levels of *K. latifolia* competition were moderate (i.e., between

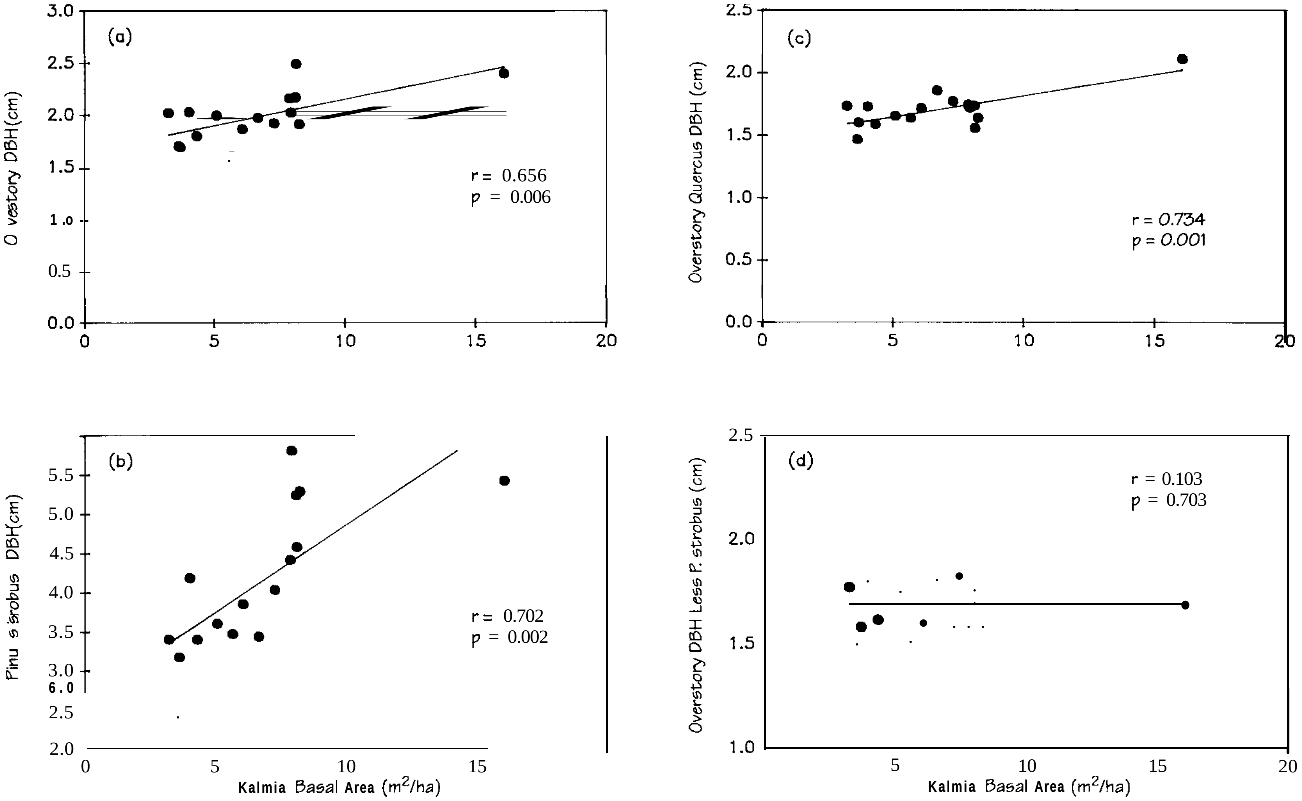

FIG. 1. Relationship between *Kalmia latifolia* basal area and (a) overstory DBH (plot is for all overstory including planted white pine (*Pinus strobus*)), (b) *P. strobus* DBH, (c) overstory *Quercus* spp. DBH, and (d) overstory DBH excluding P. *strobus* from the overstory data.

TABLE 3. Summary of species diversity (Shannon-Wiener: *H′*) and evenness (*E′*) at Blazed Creek by treatment, layer, and totals and for the reference study site by layer and totals

Site	Layers	*H′*	95% CI*	*E′*	No. of species
No Release	Overstory	2.51	±0.05	0.79	23
	Shrub	1.54	±0.06	0.48	30
	Herb	3.28	±0.08	0.81	56
	Totals	3.36	f0.01	0.77	91
Release	Overstory	2.21	f0.05	0.76	18
	Shrub	1.60	f0.05	0.50	25
	Herb	2.89	f0.06	0.76	51
	Totals	2.96	±0.01	0.71	70
BC totals	Overstory	2.45	f0.04	0.77	24
	Shrub	1.74	f0.04	0.50	32
	Herb	3.19	±0.05	0.76	64
	Totals	3.24	±0.01	0.71	95
Reference	Overstory	2.38	±0.04	0.76	22
	Shrub	1.93	f0.11	0.61	24
	Herb	2.59	f0.05	0.67	50
	Totals	2.86	±0.06	0.64	82

*Confidence intervals were determined using a t-value of 1.96 following procedures outlined by Hutcheson (1970).

clumps), high numbers of herbaceous species were observed. However, this relationship was not statistically significant.

Estimates of species evenness (E’) were highest in the herb *E’* = 0.76) and overstory layers *(E’* = 0.77) and lowest in the shrub layer *(E’ = 0.50)* across all sites (Table 3). In this layer, 93% of the density is accounted for by 11 species, and 59% of this total is due to *K. latifolia.* By comparison, 98% of the density in the overstory is also accounted for by 11 species; however, the species having the highest density (Q. *coccinea)* accounts for only 21% of the total.

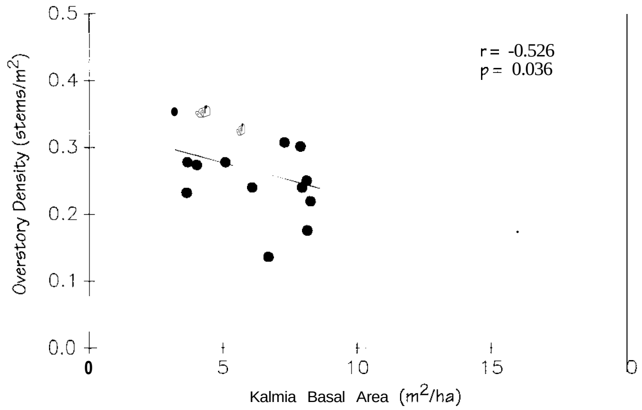

FIG. 2. Relationship between *Kalmia latifolia* basal area and overstory density.

Comparisons of species diversity with the reference sites and mixed-hardwood stands

Compared with the diversity estimates on the reference sites (J.M. Vose, unpublished data), the only nonsignificant difference found relative to the reference was the overstory on the released sites (Table 3). In all other cases, differences in diversity were significant (Table 3). When compared with

TABLE 4. Blazed Creek herbaceous layer species list and abundance summary

	Stems/m^2	Frequency	% cover
Vaccinium vacillans	5.7	0.578	3.25
Smilax glauca	3.6	0.813	1.77
Solidago arguta	2.0	0.453	0.98
Gaylussacia ursina	1.9	0.063	1.36
Pteridium aquilinum	1.9	0.563	2.95
Panicum dichotomum	1.9	0.516	0.20
Potentilla canadensis	1.9	0.313	0.33
Tephrosia virginiana	1.6	0.141	0.43
Andropogon scoparius	1.5	0.453	0.60
Pyrularia pubera	1.3	0.438	1.64
Coreopsis major	1.0	0.359	0.52
Lespedeza repens	0.8	0.188	0.10
Solidago odora	0.6	0.250	0.18
Vaccinium staminium	0.5	0.125	0.77
Epigaea repens	0.4	0.094	0.11
Eupatorium album	0.4	0.156	0.09
Viola pedata	0.4	0.109	0.04
Helianthus atrorubens	0.4	0.156	0.19
Chimaphila maculata	0.3	0.172	0.05
Gaultheria procumbens	0.3	0.031	0.03
Euphorbia corollata	0.3	0.188	0.09
Heterotheca mariana	0.3	0.109	0.08
Galax aphylla	0.3	0.031	0.05
Clitoria mariana	0.3	0.125	0.14
Helianthus microcephalus	0.3	0.109	0.10
Smilax rotundifolia	0.3	0.125	0.33
Angelica venenosa	0.2	0.094	0.05
Rubus allegheniensis	0.2	0.078	0.16
Aster undulatus	0.2	0.094	0.04
Lespedeza hirta	0.2	0.109	0.16
Smilacina racemosa	0.2	0.047	0.10
Solidago erecta	0.1	0.094	0.07
Polystichum acrostichiodes	0.1	0.031	0.11
Panicum boscii	0.1	0.047	0.05
Goodyera pubescens	0.1	0.047	0.08
Aster paternus	0.1	0.031	0.03
Uvularia pudica	0.1	0.094	0.04
Lobelia puberula	0.1	0.063	0.03
Viola spp.	0.1	0.047	0.02
Platanthera ciliaris	0.1	0.047	0.02
Baptisia tinctoria	0.1	0.047	0.17
Lysimachia quadrifolia	0.1	0.063	0.07
Aureolaria laevigata	0.1	0.078	0.14
Hieracium venosum	0.1	0.047	0.03
Silphium compositum	0.1	0.031	0.08
Lactuca canadensis	0.1	0.016	0.02
Galium pilosum	0.1	0.031	0.00
Heterotheca nervosa	0.0	0.047	0.00
Melampyrum lineara	0.0	0.047	0.03
Hypericum stragalum	0.0	0.016	0.02
Unidentified	0.0	0.031	0.00
Solidago nemoralis	0.0	0.016	0.02
Lespedeza intermedia	0.0	0.016	0.02
Hexastylus arifolia	0.0	0.016	0.03
Lilium michauxii	0.0	0.016	0.00
Aster curtisii	0.0	0.031	0.00
Prenanthes trifoliolata	0.0	0.016	0.02
Hypoxis hirsuta	0.0	0.016	0.00
Parthenocissus quinquefolia	0.0	0.016	0.00
Polygonatum biflorum	0.0	0.016	0.02
Senecio smallii	0.0	0.016	0.00
Trillium catesbaei	0.0	0.016	0.00
Aureolaria pectinata	0.0	0.016	0.02
Polygala curtisii	0.0	0.016	0.00
Total	33.2		

TABLE 4 *(concluded)*

NOTE: Species are in rank order of importance based upon density (stems/m*).

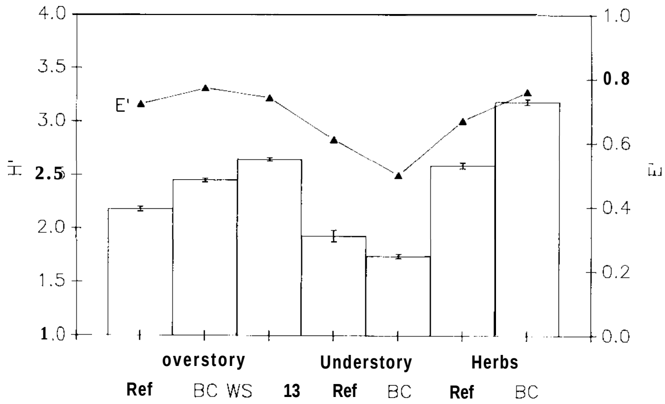

FIG. 3. Graph of species diversity (Shannon-Weiner: *H'*: bar graph) and species evenness *(E', A)* for Blazed Creek (BC), the reference study site (Ref), and an undisturbed watershed at the Coweeta Hydrologic Laboratory (WS 13) for the overstory, understory, and herb layers. Only overstory data were available for the estimate on WS 13. Error bars represent ±1 SE.

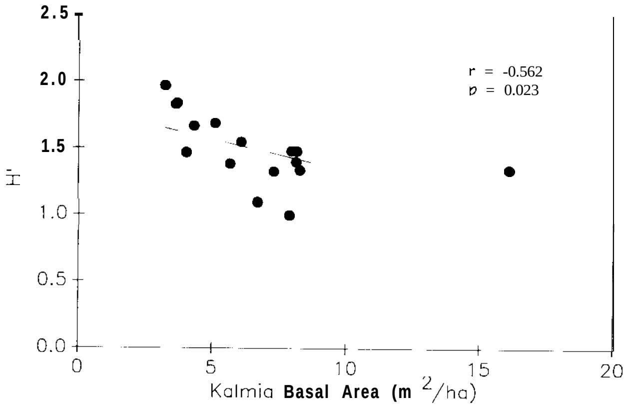

FIG. 4 Relationship between *Kalmia latifolia* basal area and species diversity *(H')* in the shrub layer.

estimates derived from historical data (Parker and Swank 1982) on an undisturbed mixed-hardwood stand at Coweeta (stems >9 cm DBH; collected in 1935), species diversity was significantly lower in the overstory at BC for site totals and by treatments (Fig. 3).

In all, 64 species were identified in the herb layer at BC (Table 4). By comparison, the reference study sites contained 50 species in this layer, and they were less evenly distributed

(Fig. 3), resulting in a significantly lower estimate of species diversity (H' = 2.59). One explanation for this difference is that many of the species occurring at BC, such as ***Lespedeza*** spp. and ***Clitoria mariana*** L., were early successional legumes, often associated with fire, which still occupied the site. In addition, members of the family Poaceae were more important at BC, again, likely due to the site's early stage of development.

The rigor of the comparisons depends on the similarity of the stands in all ways other than the imposed treatment. Based on experience and a limited amount of pretreatment stand information at BC, we believe that the reference stand is representative of pretreatment conditions at BC; however, we have no way of verifying this assumption. In a related study (Swift et al. 1993), we were measuring first- and second-year vegetation diversity response on stands where we have both pretreatment information and control stands (these data are serving as the "reference stand" in the present analysis). However, confirmation (or rejection) of the results observed in the analysis must await more long-term measurements.

Summary and conclusions

Examination of sites 13 years after site preparation burning indicates that this treatment does not substantially alter the dominance of the evergreen-shrub ***K. latifolia*** in these xeric, pine-hardwood ecosystems. However, satisfactory establishment and growth of planted ***P. strobus*** shows that felling and burning reduces ***K. lutifoliu*** vigor long enough to be effective. In addition, burning produced site conditions adequate for seed germination by other pine species, particularly ***P.*** *rigida*, which historically has been an important overstory component of xeric and subxeric sites in the southern Appalachians. At high ***K. latifoliu*** basal areas, overstory density decreased and stem diameter increased, indicating that ***K.*** *lutifoliu* restricted survival of regenerating stems. However, once stems reached the overstory their growth rates were greater, perhaps as a result of reduced competition between overstory species. ***Kulmiu lutifoliu's*** influence on shrub diversity suggests that future recruitment of seedlings to the overstory may be restricted because of reduced availability of hardwood stems in the form of advanced regeneration. It also suggests that the type of species available for recruitment to the overstory would be skewed toward species that can become established under extremely low light conditions typical of ***K.*** *latifolia* thickets.

Mechanical release reduced the number of species and estimates of diversity at BC without affecting species evenness. Nevertheless, herb-layer diversity was greater at BC than on the reference watershed, while diversity of the shrub layer was lower. The overwhelming presence of ***K. lutifolia*** in the shrub layer at this early stage of development is likely the reason for the lower diversity estimates. There were no differences in overstory species diversity.

The influence of *K.* ***lutifoliu*** upon diversity estimates was greatest in the shrub layer because of its overwhelming dominance. Although the shrub layer on the reference sites contained a substantial amount of ***K. latifoliu,*** its influence on diversity was not as great as at BC. This may be due to stand development, and over time, ***K.*** *latifolia*'s influence on species diversity may decrease on the BC sites as well.

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