The influence of mountain laurel on regeneration in pitch pine canopy gaps of the Coweeta Basin, North Carolina, U.S.A.

Jayson R. Waterman, Andrew R. Gillespie, James M. Vose, and Wayne T. Swank

Abstract: Because of its dense nature, mountain laurel (*Kalmia latifolia* L.) understories may be retarding the regeneration of xeric pitch pine (*Pinus rigida* Mill.) sites in the southern Appalachians and thereby influencing successional dynamics. This study examined the impact of the laurel understory on hardwood successional ecology in living pitch pine stands and pine gaps at their upper and lower elevational distribution. The laurel understory was physically removed from half the plots; the remaining plots served as a control. The plots were inventoried and all seedlings were tagged and measured to determine importance values, recruitment, survivorship, and biomass for 2 years following treatment. The results indicate that the presence or absence of the laurel understory does not affect initial seedling recruitment, survivorship, or their relative competitiveness. However, mountain laurel does suppress growth of smaller seedlings. Given the higher importance value, recruitment, and survivorship of red maple (*Acer rubrum* L.), the regeneration layer in these pitch pine sites is currently dominated by red maple, with scarlet oak (*Quercus coccinea* Muenchh.) and other xeric-site hardwoods as associates. With the adaptive ability of red maple to take advantage of openings, red maple will continue to dominate and ultimately regenerate these communities with other hardwoods as minor associates.

Resume : À cause de sa nature dense, les sous-bois de kalmia a larges feuilles (*Kalmia latifolia* L.) pourraient retarder la regeneration de pin rigide (*Pinus rigida* Mill.) sur les sites xeriques dans le sud des Appalaches et influencer ainsi les dynamiques successionnelles. Cette etude examine l'impact du sous-bois de kalmia sur l'écologie successionnelle des feuillus dans les peuplements de pin rigide vivant et dans les trouées de pin dans les zones les plus basses et les plus élevées de leur aire de distribution géographique. Le sous-bois de kalmia a été enlevé de facon mécanique dans la moitié des parcelles; les autres parcelles ont servi de témoin. Les parcelles ont été inventoriées et tous les semis ont été marques et mesures pour determiner les valeurs d'importance, le recrutement, la survie et la biomasse pendant les 2 annees qui ont suivi le traitement. Les résultats montrent que la presence ou l'absence de sous-bois de kalmia n'affecte pas le recrutement initial des semis, ni leur survie, ni leur compétitivité relative. Cependant, le kalmia a larges feuilles réduit la croissance des semis les plus petits. Étant donné que la valeur d'importance, le recrutement et la survie sont les plus élevés pour 1'erable rouge (*Acer rubrum* L.), la strate de regeneration dans ces sites de pin rigide est actuellement dominée par 1'erable rouge, avec le chêne écarlate (*Quercus coccinea* Muenchh.) et d'autres feuillus typiques des sites xeriques comme associés. Avec la capacité d'adaptation de 1'erable rouge, qui permet a cette essence de tirer profit des ouvertures, celui-ci va continuer a dominer et ultimement a regenerer des communautés avec d'autres feuillus comme essences compagnes moins importantes.
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Introduction

The southern Appalachian Mountains contain some of the highest species richness in the eastern U.S. This region forms the southern edge of the ranges of many boreal and northern species, and the northern edge of many southern species. In addition, the terrain is often steep and dissected. As such, species assemblages in the southern Appalachians vary over relatively short distances in response to environmental gradients in the landscape. In his classic study of the vegetation of the Great Smoky Mountains, Whittaker (1956) identified 15 different communities along elevational and moisture gradients. On an elevational gradient, these ranged from high elevation spruce-fir boreal forests to low elevation cove hardwood forests. On a moisture gradient, the mesic cove forests gave way to more xeric hardwoods that then turned to pine communities on the most xeric sites.

Whittaker (1956) found that the overstory on xeric sites was primarily composed of Virginia pine (*Pinus virginiana* Mill.), pitch pine *(Pinus rigida* Mill.), table mountain pine *(Pinus pungens* Lamb.), scarlet oak (*Quercus coccinea* Muenchh.), and blackjack oak *(Quercus marilandica* Muenchh.). The dominant pine species changed from Virginia pine to pitch pine around 700 m elevation. An ericaceous shrub layer composed of mountain laurel (*Kalmia latifolia*L.), huckleberry *(Gaylussacia* spp.), and blueberry (*Vaccinium* spp.) was found in the understory of pitch pine stands, forming a community Whittaker (1956) called a "pitch pine heath." Whittaker's (1956) pitch pine heath was dominated by pitch pine in the overstory with scarlet oak, chestnut oak *(Quercus prinus* L.), American chestnut *(Castanea dentata* (Marsh.) Borkh.), blackgum *(Nyssa sylvatica* Marsh.), red maple *(Acer rubrum* L.), and sourwood (*Oxydendrumarboreum* (L.) DC.) as important associates. Again, mountain laurel, blueberry, and huckleberry dominated the understory. Shrub coverage was found to be almost always over 50% and occasionally up to 70%.

Historically, fire has been an important disturbance factor in pitch pine heath communities, but with the suppression of fire after the initial part of this century (Barden and Woods 1976; Harmon 1982), communities have been subject to different patterns and intensities of fire and related disturbances leading to slow shifts in composition (Harmon et al. 1983). In the xeric pitch pine communities, an important contemporary disturbance is periodic infestations of the southern pine beetle *(Dendroctonus frontalis* Zimm.) that usually occur in combination with drought. The majority of gaps associated with pine stands are large, multiple-tree gaps caused by these southern pine beetle outbreaks (Kuykendall 1978). However, as early as 1945, Hoffmann and Anderson (1945) reported that pine gaps in the southern Appalachians were regenerating to hardwoods, including red maple and scarlet oak; almost no pine regeneration was found. Similarly, Smith (1991) found that the formation of pitch pine gaps shifted overstory composition from pitch pine to scarlet oak and chestnut oak with other minor hardwoods as associates. In his examination of pitch pine gaps of varying ages in the Coweeta Basin of North Carolina, Smith (1991) also found that oaks and red maple became more important in the understory over time, while the mountain laurel component remained relatively constant. In his study, Whittaker (1956) concluded that the dense evergreen laurel understory inhibited regeneration of overstory species. This suggests that the composition of successional vegetation may not include overstory hardwoods in all cases. More recent studies further substantiated the effects of mountain laurel on regeneration (Smith 1991; Clinton et al. 1993). Light levels under the mountain laurel canopy are approximately 2% of full sunlight, well below optimal levels for seedling growth (Chapman 1950, Whittaker 1963). Hence, removal of the mountain laurel understory should increase light penetration to the forest floor and perhaps enhance seedling establishment and growth. This may prove important where the reintroduction of prescribed burning for understory control and stand conversion through planting after burning are becoming important silvicultural tools in National Forests of the Appalachians (Swift et al. 1993).

This study was undertaken to determine the role of mountain laurel in pitch pine gap dynamics. Specifically, the objectives of this study were (*i*) to determine the effects of mountain laurel on pitch pine stand and gap regeneration, productivity, and species composition; *(ii)* to compare recruitment between plots with intact mountain laurel and plots where mountain laurel had been removed; *(Hi)* to compare species dynamics in pitch pine stands and gaps at different elevations corresponding to the upper and lower elevational boundaries found by Whittaker (1956); and *(iv)* to compare productivity in pitch pine stands and gaps at these same elevations.

Methods

Study site description

This study was conducted at the United States Forest Service (USFS) Coweeta Hydrologic Laboratory in southwestern North Carolina (35°03'N, 83°25'W). Coweeta is an experimental forest located in the Blue Ridge physiographic province of the Nantahala Mountain Range of the southern Appalachians with elevations ranging from 670 to 1592 m. Study sites were located at two elevations, 670 and 950 m, and were south- to southwest-facing on upper slopes, providing a xeric environment. Composition of these sites, and most pine stands and gaps in the Coweeta Basin, consists of pitch pine, chestnut oak, scarlet oak, red oak *(Quercus rubra* L.), blackgum, and sourwood as the major species contributing to basal areas of 32.3 $m^2 \cdot ha^{-1}$ in live stands and 6.5 and 13.0 $m^2 \cdot ha^{-1}$ in 3- and 8-year-old gaps, respectively (Smith 1991). Soils are in the Cowee-Evard complex, a fine loamy, mixed, mesic Typic Hapludult characterized by a clay-loam layer from 30 to 60 cm deep. The sites correspond to the elevational limits of the pitch pine heath found by Whittaker (1956) in the Great Smoky Mountains. Mountain laurel forms a dense canopy 2-3 m tall with a basal area of 20-30 $m^2 \cdot ha^{-1}$. The 5- to 6-year-old canopy openings examined in this study ranged from 500 to 1000 m^2. The light flux environment in these openings in June (midyear with highest sun position) was 10–350 $\mu mol \cdot m^{-2} \cdot s^{-1}$ under variable mountain laurel cover, regardless of the overstory condition. Light values at the forest floor were as high as 850 $\mu mol \cdot m^{-2} \cdot s^{-1}$ with laurel removed under full pine canopy cover and 1300 $\mu mol \cdot m^{-2} \cdot s^{-1}$ where laurel had been removed in a pine gap.

Experimental approach

A factorial combination of two pine overstory treatments (living overstory or canopy gap) and two mountain laurel treatments (intact or manually removed) was used with complete replication at the two elevations. Each treatment combination was replicated four times at each elevation to produce a total of 32 plots. Plots were 10 X 10 m with

Table 1. Woody species occurring in sampled pitch pine - mountain laurel communities of the Coweeta Basin, North Carolina.

Species code	Scientific name	Common name
STM	*Acer pensylvanicum* L.	Striped maple
REM	*Acer rubrum* L.	Red maple
DOS	*Amelanchier arborea* (Michx.) Fern.	Downy serviceberry
SWS	*Calycanthus floridus* L.	Sweetshrub
HIC	*Carya glabra* (Mill.) Sweet	Pignut hickory
AMC	*Castanea dentata* (Marsh.) Borkh.	American chestnut
ALC	*Castanea pumila* Mill.	Allegheny chinkapin
DOG	*Cornus florida* L.	Flowering dogwood
HUC	*Gaylussacia* spp.	Huckleberry
WIH	*Hamamelis virginiana* L.	Witch-hazel
MOW	*Ilex montana* Torr. & Gray	Mountain winterberry
MOL	*Kalmia latifolia* L.	Mountain laurel
BLG	*Nyssa sylvatica* Marsh.	Blackgum
SOW	*Oxydendrum arboreum* (L.) DC.	Sourwood
PIP	*Pinus rigida* Mill.	Pitch pine
WHP	*Pinus strobus* L.	Eastern white pine
BUN	*Pyrularia pubera* Michx.	Buffalo nut
SCO	*Quercus coccinea* Muenchh.	Scarlet oak
BJO	*Quercus marilandica* Muenchh.	Blackjack oak
CHO	*Quercus prinus* L.	Chestnut oak
BLO	*Quercus velutina* Lam.	Black oak
RHO	*Rhododendron maximum* L.	Rosebay rhododendron
WIS	*Rhus copallina* L.	Winged sumac
SAS	*Sassafras albidum* (Nutt.) Nees	Sassafras
SWL	*Symplocos tinctoria* (L.) L'Her	Sweetleaf
POI	*Toxicodendron radicans* (L.) Kuntze	Poison-ivy
BLB	*Vaccinium* spp.	Blueberry

Note: Nomenclature follows that of Little (1979).

a 5 X 5 m measurement plot nested within. For biomass and species composition measurements, a 1 X 5 m plot was nested within the 5 X 5 m plot. Mountain laurel treatments were randomly applied to the plots at the lower elevation to produce the four replications of each treatment. At the higher elevation site, however, half of the plots were located just within a gauged watershed. Because this watershed serves as a control watershed for long-term studies, no mountain laurel was removed on these plots. Laurel removal treatments were applied to identical areas just on the opposite side of the shoulder slope defining the watershed. Hence, the mountain laurel treatments were not applied in a random manner at this elevation; however, there were no obvious differences between cut and intact plots. The mountain laurel was cut and removed from treated study plots during the winter of 1991-1992. Care was taken to minimize damage to residual vegetation.

After the mountain laurel treatments were applied, the plots were inventoried for tree seedlings (including both new recruits and advanced regeneration), and all seedlings in the 5 X 5 m measurement plots were permanently tagged (Table 1). During the fall of 1992, all woody stems in the 1 X 5 m plots were inventoried and permanently tagged. Additionally, diameter at ground level was measured on all stems less than 2.5 cm DBH; DBH was measured on all stems less than 10.0 and greater than 2.5 cm DBH. The plots were reinventoried and measured during the fall of 1993, and recruitment inventories tallied all new tree stems in the 5 X 5 m plots by species. These data were used to calculate importance values for each species for each stand type and mountain laurel treatment. Importance values were calculated as the sum of the relative frequency, density, and dominance or basal area (Curtis and McIntosh 1951).

Biomass was calculated using allometric equations. Most biomass was calculated using species-specific equations based on those of Elliott and Clinton (1993). For some species, biomass equations did not exist; in these circumstances, equations of species with similar growth form were substituted. These species were relatively rare (e.g., poison ivy *(Toxicodendron radicans* (L.) Kuntze) with one stem) and in total made up less than 2% of the total biomass (see Table 3). Biomass of huckleberry and poison ivy was estimated using Elliott and Clinton's (1993) equation for blueberry. American chestnut biomass was estimated with the equation for Allegheny chinkapin *(Castanea pumila* Mill.), identification being accomplished by the color of the underside of the leaf. Additionally, the Elliott and Clinton (1993) equation for blackgum was used to estimate sweetleaf *(Symplocos tinctoria* (L.) L'Her) biomass and the five stems of downy serviceberry *(Amelanchier*

Table 2. Relative frequency (Freq.), density (Dens.), and dominance (Dom.) in 1992 and importance values for 1992 and 1993 (IV-92 and IV-93) for woody stems <10 cm DBH, and mean seedling recruitment and survival (and SE) of major species in pitch pine stands in the Coweeta Basin, excluding mountain laurel and rhododendron.

Species*	Freq.	Dens.	Dom.	IV-92	IV-93	Recruitment	Survivorship
REM	0.166	0.081	0.148	0.395	0.396	384.38 (65.7)	0.924 (0.04)
STM	0.007	0.001	0.000	0.008			
DOS					0.036	34.38 (19.9)	
SWS	0.020	0.035	0.007	0.062	0.066		
HIC	0.007	0.003	0.046	0.056	0.024	6.25 (6.3)	
AMC	0.040	0.013	0.034	0.087	0.099	31.25 (12.2)	
ALC	0.007	0.004	0.013	0.024	0.044	28.13 (16.9)	
DOG	0.013	0.002	0.000	0.015	0.033	31.25 (15.8)	
HUC	0.132	0.492	0.095	0.719	0.724		0.696 (0.08)
WIH	0.013	0.003	0.000	0.016	0.031		
MOW	0.007	0.001	0.000	0.008	0.014		
BLG	0.086	0.066	0.382	0.534	0.363	21.88 (9.8)	0.577 (0.12)
SOW	0.007	0.002	0.019	0.028	0.023	25.00 (15.6)	
PIP						3.13 (3.1)	
WHP	0.013	0.002	0.000	0.015	0.021	6.25 (6.3)	
BUN	0.060	0.056	0.006	0.122	0.139		
SCO	0.126	0.081	0.014	0.221	0.211	168.75 (32.5)	0.822 (0.06)
BJO	0.020	0.009	0.041	0.070	0.052	3.13 (3.1)	
CHO	0.013	0.002	0.042	0.057	0.064	6.25 (4.3)	
BLO	0.020	0.004	0.001	0.025	0.031	6.25 (4.3)	
WIS	0.007	0.003	0.000	0.010	0.011		
SAS	0.040	0.010	0.001	0.051	0.025	31.25 (17.1)	
SWL	0.106	0.036	0.133	0.275	0.360	187.50 (44.2)	0.990 (0.01)
POI	0.007	0.001	0.001	0.009	0.008		
BLB	0.086	0.090	0.015	0.191	0.228		0.934 (0.04)

*Species codes as defined in Table 1.

arborea (Michx. f.) Fern.). At this size, sweetleaf was distinguished from blackgum by the taste of the leaf. The biomass of flowering dogwood (*Cornus florida* L.) was calculated using the equation of Boring and Swank (1984). Sweetshrub (*Calycanthus floridus* L.) biomass, found on only one plot, was estimated using Boring and Swank's (1984) equation for dogwood. The biomass of mountain laurel and rhododendron (*Rhododendron maximum* L.), with a basal diameter greater than 46 mm, was estimated with equations based on those of McGinty (1972). For laurel and rhododendron stems less than 46 mm in basal diameter, the equations of Boring and Swank (1984) were used. Sapling biomass (2.5 < DBH < 10.0 cm) was calculated using equations from Phillips (1981).

Statistical analyses

Analysis of variance was used to determine the effects of pine overstory, elevation, and mountain laurel on recruitment, seedling survivorship, importance values, and biomass. This was done for all tree seedlings as a whole and for the major individual species. The approach was to evaluate laurel removal in individual stand types (e.g., high elevation living overstory) with one-way analyses (3 df using the F-statistic for evaluating the two laurel treatments). Next, elevation and pine overstory condition were tested with laurel removal using a two-way factorial design (31 df using the F-statistic for main and interaction effects). Importance value analyses required pooling the four plots in each laurel treatment in each stand type (7 df) as relative frequency across plots was calculated as a component of importance. Analysis of covariance was used to determine the effects of mountain laurel on the amount of growth (increase in biomass) for live and dead overstories separately (15 df). Initial biomass was used as a covariate for all tree species combined and for each major tree species individually. If the mountain laurel - pine overstory interaction was found to be significant, the mountain laurel treatments were redefined numerically (0, control; 1, removal), and regression analysis was used to model and interpret data patterns.

Results

Importance values

Based on inventories in the 1 X 5 m subplots, importance values were calculated for each species in 1992 and 1993 (Table 2). Mountain laurel and rhododendron were omitted in the calculation of importance values so that the cut and control plots could be compared directly. Red maple, scarlet oak, blackgum, and sweetleaf were the four most important tree species; maximum importance values for these species ranged up to 84.1, 41.0, 89.5, and 81.9, respectively. There

Table 3. Mean biomass (kg·ha^{-1}) and growth (and SE) of woody stems <10 cm DBH in pitch pine communities in the Coweeta Basin, North Carolina.

	Control plots			Cut plots		
Species*	1992	1993	Growth	1992	1993	Growth
REM	344.90 (312.5)	686.90 (646.1)	342.00 (333.7)	532.09 (242.5)	730.38 (331.6)	198.29 (121.1)
STM	0.23 (0.2)		-0.23 (0.2)			
DOS		0.74 (0.6)	0.74 (0.6)		2.28 (1.7)	2.28 (1.7)
SWS	0.98 (1.0)	2.75 (2.7)	1.77 (1.8)	15.47 (13.6)	23.71 (23.5)	8.24 (10.2)
HIC				181.37 (181.4)	183.48 (183.5)	2.11 (2.1)
AMC	86.07 (84.7)	123.81 (120.6)	37.74 (35.9)	1 166.27 (1160.3)	1 169.88 (1160.1)	3.61 (2.6)
ALC		0.01 (0.0)	0.01 (0.0)	179.96 (180.0)	303.04 (303.0)	123.08 (123.1)
DOG		21.66 (85.81)	21.66 (21.4)	2.79 (1.9)	5.26 (3.6)	2.47 (1.7)
HUC	18.01 (12.1)	17.02 (12.5)	-0.99 (1.2)	93.20 (27.4)	114.41 (33.9)	21.76 (7.3)
WIH	0.43 (0.4)	59.43 (59.4)	58.99 (59.0)	0.96 (1.0)	1.16 (1.2)	0.20 (0.2)
MOW	0.20 (0.2)	1.06 (0.8)	0.86 (0.8)			
MOL	21 071.51 (5870.6)	23 637.65 (5965.9)	2566.15 (1440.9)			
BLG	2 372.11 (2259.1)	2 940.51 (2803.1)	568.91 (544.1)	120.33 (73.8)	169.84 (87.7)	49.51 (40.0)
SOW				49.61 (49.6)	66.33 (66.3)	16.71 (16.7)
WHP		0.06 (0.1)	0.06 (0.1)	0.30 (0.3)	0.59 (0.5)	0.29 (0.3)
BUN	11.29 (5.6)	19.82 (9.3)	8.53 (3.9)	5.77 (5.1)	16.68 (14.2)	10.91 (9.0)
SCO	20.42 (9.1)	20.89 (12.8)	0.47 (5.4)	47.40 (17.2)	69.38 (28.1)	21.98 (15.1)
BJO	2.63 (2.6)	2.71 (2.1)	-0.54 (0.5)	801.44 (801.1)	832.94 (832.5)	31.50 (31.5)
BLO				6.00 (4.2)	8.20 (6.6)	2.20 (2.6)
WIS				1.58 (1.6)	3.90 (3.9)	2.32 (2.3)
CHO	3 251.74 (3251.7)	3 444.82 (3444.8)	193.08 (193.1)			
RHO	1 562.02 (1562.0)	1 586.08 (1586.1)	24.06 (24.1)			
SAS	4.18 (4.0)		-4.18 (4.0)	4.85 (2.8)	2.14 (1.6)	-2.71 (2.9)
SWL	3.73 (1.3)	6.80 (2.0)	3.07 (0.9)	799.62 (38.1)	8 236.08 (45.2)	236.46 (211.3)
POI	0.43 (0.4)	0.47 (0.5)	0.04 (0.0)			
BLB	8.85 (4.3)	11.87 (6.1)	3.02 (1.9)	8.54 (3.8)	12.91 (3.9)	4.38 (2.2)
Total	24 955.49 (6018.3)	32 584.44 (6473.8)	3824.72 (1586.0)	11 221.95 (7858.4)	11 958.43 (8056.6)	736.49 (255.6)
All trees	6 085.99 (4001.7)	7 248.29 (4693.9)	1162.30 (878.7)	11 092.04 (7850.2)	11 779.82 (8048.6)	687.78 (257.0)

*Species codes as defined in Table 1.

were no significant differences ($p > 0.10$) for importance values of any species with elevation or pine overstory differences, nor for the mountain laurel removal treatment. For example, in 1992, elevation ($p = 0.55$), condition of the pine overstory (p - 0.81), and laurel removal ($p = 0.69$) had no influence on red maple importance. Similar patterns were observed for all major species in both 1992 and 1993.

Recruitment

Recruitment inventories indicated that red maple was the most common species recruited, followed by scarlet oak and sweetleaf (Table 2). Red maple recruitment was up to 7.5 seedlings per plot, whereas scarlet oak recruitment was up to 3.0. Sweetleaf recruitment ranged up to 4.25 seedlings per plot. Neither the condition of the pine overstory ($p = 0.92$) nor the mountain laurel treatments ($p = 0.70$) had a significant influence on the number of stems recruited. Similarly, the species richness of the recruits was not significantly affected by the pine overstory ($p = 0.83$) or the mountain laurel treatments ($p = 0.29$). On examining each of the three most common species recruited, the pine overstory and the mountain laurel treatments were not significant ($p > 0.10$).

Survivorship

Survivorship for each species was calculated as the proportion of individuals surviving from one year to the next (Table 2). Red maple and sweetleaf survivorship was almost always over 90%. Survivorship of scarlet oak ranged from 47 to 100%. Blackgum survivorship was quite variable; it ranged from 0 to 100%. Analysis of variance was used to determine the effect of mountain laurel removal on the survivorship of the tree species with the highest importance values (red maple, scarlet oak, blackgum, and sweetleaf). The mountain laurel treatments did not significantly affect the survivorship of red maple, blackgum, or sweetleaf ($p > 0.10$). However, scarlet oak had significantly higher survivorship on plots where the mountain laurel had been removed ($p = 0.091$). The relatively high p-values indicate that the mountain laurel understory was not greatly affecting seedling survivorship in any species, although scarlet oak did show a biological response.

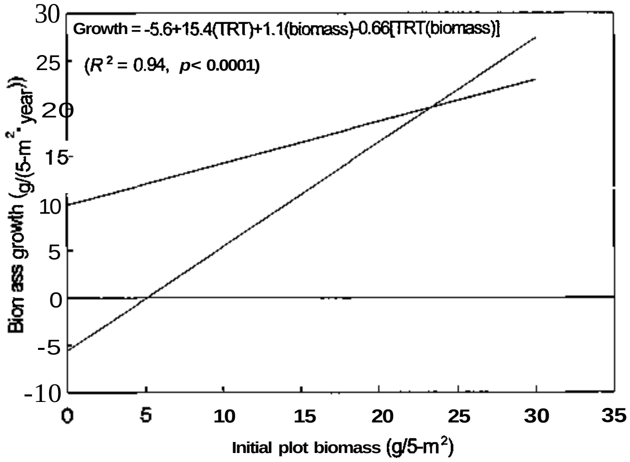
Biomass

Where present, mountain laurel made up the largest proportion of the biomass; in some cases, mountain laurel accounted for 98% of the standing biomass (Table 3). Where the mountain laurel had been removed, tree seedling biomass was generally between 100 and 200 $g \cdot m^{-2}$. On the control plots, the biomass of tree seedlings (i.e., <2.5 cm DBH) was generally less than 50 $g \cdot m^{-2}$, although the presence of saplings (≥2.5 and <10 cm DBH) increased this to over 1300 $g \cdot m^{-2}$.

The mountain laurel removal treatment did not significantly affect the biomass growth of blackgum or sweetleaf in either the living pine stands or the pine gaps (p > 0.10). For scarlet oak, mountain laurel did not influence growth in the pine gaps. In the living pine stands, however, growth of scarlet oak was significantly higher in plots where mountain laurel had been removed (p = 0.0882).

The mountain laurel treatment did not significantly affect growth of red maple in pine gaps, but a significant interaction with the initial biomass was found in living pine stands (p = 0.0082). Also, mountain laurel treatments in the living pine stands were not impacting on growth of all tree species combined, but a significant interaction with the initial biomass was found in pine gaps (p = 0.0139). After redefining the mountain laurel treatments as numerical values (0, control; 1, removal) to quantify treatment effects on slope and intercept coefficients, regression analysis revealed that red maple growth under a living pine overstory was higher where the mountain laurel had been removed until initial maple biomass reached 4.68 $g \cdot m^{-2}$ (23.39 $g/5\text{-}m^2$ sample plot), which corresponded to large seedlings with a mean basal diameter of 49.9 mm (R^2 = 0.937). After maple biomass reached this level, growth was higher where the laurel understory was intact (Fig. 1). A similar regression revealed that total tree growth (i.e., all tree species combined) in the pine gaps was higher until tree biomass reached 1470.73 $g \cdot m^{-2}$, which corresponded to saplings with a mean DBH of 76.4 mm (R^2 - 0.833). Tree growth was greater in the control plots after this level was reached.

Fig. 1. Interacting effects of initial plot biomass and mountain laurel treatment (0, intact; 1, removed) on biomass growth of red maple seedlings.



Discussion

Mountain laurel was not a significant factor in the short-term successional dynamics of the pitch pine communities studied. The importance values of major species were not influenced by mountain laurel or the condition of the pine overstory. This indicated that the competitive ability of seedlings of each regenerating hardwood species was not affected by mountain laurel or the pitch pine. This was also reported by Chapman (1950). All of the major regenerating species were present as advance regeneration in similar proportions in both the pine stands and pine gaps.

Initial tree seedling recruitment was unaffected by the presence of the mountain laurel understory or pine overstory. The lack of importance of the pine overstory may be related to scattered and generally low density (e.g., <100 stems/ha) of pine in these ecosystems (Vose et al. 1993). The forest floor was disturbed as little as possible, and the mountain laurel litter present in all plots could have been affecting the recruitment of some species, possibly through allelopathy, as other laurel species in the genus are known to inhibit germination and growth of tree seedlings (Damman 1971; Mallik 1987; Zhu and Mallik 1994). If mountain laurel litter does have a major role in limiting seedling recruitment, then the importance of fire (Harmon et al 1983) in regenerating these stands is further substantiated because fire consumes the upper litter layer (Vose and Swank 1993). Kittredge and Ashton (1990) also found that mountain laurel density did not inhibit seedling establishment in three mixed hardwood - conifer stand types in New England. Because our study only followed recruitment for two growing seasons, our results must be interpreted carefully. For example, the higher red maple recruitment could be at least partially due to its constant and prolific seed production. Scarlet oak, on the other hand, produces large amounts of seed only sporadically. Thus, oak recruitment may experience a dramatic increase after a season of high acorn production; this did not occur during this study. Clearly, the timing of seed production and the timing and duration of disturbance effects are important factors that warrant further study.

With the exception of scarlet oak, seedling survivorship was unaffected by mountain laurel. Scarlet oak had slightly higher survivorship when mountain laurel was removed. The mechanism for this response is unknown, but scarlet oak survival might be enhanced by greater light and (or) water availability in the cut stands. Apparently, changes in microclimate have less of an effect on seedling survival of other species.

In terms of biomass growth, analysis of covariance indicated that mountain laurel influences tree seedling growth, especially red maple. Small seedlings exhibited higher growth rates in plots without mountain laurel. Laurel suppressed small (i.e., <2.5 cm DBH) seedling growth, and once released, seedlings showed a significant growth response. Interestingly, larger stems (2.5 > DBH < 10.0 cm) grew better with the laurel understory intact. These saplings had managed to overtop the laurel canopy and were no longer experiencing the laurel's heavy shade. Chapman (1950) found that wind velocities in areas cleared of mountain laurel were twice that of areas with intact laurel. One possible explanation is that the laurel understory may be acting as a windbreak and consequently reducing wind-associated desiccation. With this protection, stems with adequate light exposure experienced higher growth rates. Without the protection of the laurel, the growth rates were reduced.

Generally, red maple had the highest importance value and recruitment in the stands studied. It also had the highest biomass growth rate. Since the mountain laurel understory did not favor any species over another, red maple should continue to be the dominant species in the regeneration layer of these pitch pine communities, barring any major disturbances such as fire. If such a disturbance occurs, the fire-intolerant red maple would most likely be more negatively affected than the associated fire-tolerant oak species.

A reduction in landscape biodiversity may occur as pine disappears and red maple dominates many of these sites to the exclusion of other species. These poor, xeric sites do not currently produce valuable hardwood or pine timber. Thus, management of these communities may be best served by focusing on wildlife habitat. However, U.S. Forest Service management of these sites on National Forest lands may change with growing interests in prescribed burning for habitat restoration. With the use of prescribed fire, these pitch pine communities might be reestablished as part of the natural landscape.

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