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Abstract

Percent cover of seven forage species utilized by bobwhite quail (*Colinus virginianus*) was determined before thinning and 2 and 4 years after thinning a 35-year-old loblolly pine-hardwood stand. Combinations of three loblolly pine (15, 18, and 21 m^2/ha) and three hardwood (0, 3.5, and 7 m^2/ha) basal areas were replicated three times. Percent cover was determined for American beautyberry (*Callicarpa americana*), blackberry (*Rubus* spp.), tick trefoil (*Desmodium* spp.), lespedeza (*Lespedeza* spp.), panic grass (*Panicum* spp.), yellow wood sorrel (*Oxalis stricta*), and three-seeded mercury (*Acalypha* spp.). Percent cover of American beautyberry and blackberry increased with time. Tick trefoil and panic grass were negatively related to time after thinning. However, lespedeza, yellow wood sorrel, and three-seeded mercury were not influenced significantly by time after thinning. Blackberry and panic grass were negatively related to pine basal area, while all other plant species were not affected. Three-seeded mercury was the only species not negatively related to hardwood basal area. Canopy cover and relative light intensity in the understory demonstrated an inverse relationship.

Introduction

Northern bobwhite quail (*Colinus virginianus*) populations are declining throughout the southeastern United States (Klimstra, 1982). Historically, bobwhite quail have inhabited primarily agricultural lands which provide a diversity of habitats such as crop fields, fence rows, and pastures. However, availability of this type of habitat in the Southeast has been affected by reduction or abandonment of farmlands (Sorrow and Webb, 1982). Thus, bobwhite quail in the southeastern United States primarily occur in pine and mixed pine-hardwood forests (Bell et al., 1985). Consequently, effects of timber management practices on bobwhite quail habitat can have a profound effect on their numbers. Plants producing seeds and soft mast can be influenced dramatically by prescribed fire, overstory canopy removal, and other silvicultural treatments. Seeds and soft mast provide important energy sources for bobwhite quail throughout the year.

Approximately 31% of private forest land in Arkansas is owned by forest industries (Beltz et al., 1992). These forested lands are often intensely managed with clearcuts and short rotations that are not always favorable to bobwhite quail. Young clearcut stands, reforested as even-aged pine plantations, initially provide adequate to excellent food sources for bobwhite quail (Sorrow and Webb, 1982). After 2-3 years, however, these stands provide little foraging opportunity for bobwhite quail as many of the seed and soft mast producing plants are shaded out or out competed by increasing woody plants. Increasing litter depth also inhibits bobwhite quail from foraging efficiently on available food sources. Much of the nonindustrial private forest land in Arkansas is unmanaged, resulting in poor habitat for bobwhite quail. Overstory stocking in many of these stands is too high to permit adequate sunlight to reach the forest floor. Thick litter depth and sparse understory vegetation common in these stands impede bobwhite quail from foraging efficiently.

Silvicultural practices such as prescribed burning and thinning can be used to improve bobwhite quail habitat (Landers and Mueller, 1986). Controlled burns reduce litter build up, release nutrients, and promote herbaceous plant growth. Thinning reduces stand basal area, which promotes herbaceous plant growth by opening the stand's canopy allowing additional sunlight to reach the understory. Recommended thinning of a pine stand for improving bobwhite quail habitat is to retain a basal area in ft^2/acre numerically equal to the site index (tree height in feet at fifty years of age) minus a value of 25 (Landers and Mueller, 1986). Control of midstory hardwoods, which produce twice as much shading as the same pine basal area, can also help improve bobwhite quail habitat (Tappe et al., 1993). Midstory hardwoods that occur in pine dominated stands are generally too small in size and low in vigor to produce hard mast which could supplement a bobwhite quail's diet of insects, seeds, and soft mast (Landers and Mueller, 1986). The objective of this study was to determine how residual pine and hardwood basal areas after a thinning operation affect the herbaceous plants that produce seeds, soft mast, and forage for bobwhite quail.

Matrials and Methods

Study Area.--The study was established in a natural, even-aged, 35-year-old loblolly pine (*Pinus taeda*)-hardwood stand located in the School Forest of the University of Arkansas at Monticello, Drew County, Arkansas. Soils of the area were mapped as Henry (Typic Fragiaqualfs) and Calloway (Flossaquic Fragiaqualfs) series (Larance et al., 1976). Both soils have silt loam surfaces and were formed on windblown silt. These poorly drained soils occur on broad upland flats and have a site index of 28 m at 50 years for loblolly pine.

The present stand was naturally regenerated from an existing hardwood-pine stand in the early 1950's; the hardwood component was killed, and a new loblolly pine stand established from seeds produced by residual trees. A few remnants of the original forest stand still existed prior to study installation. This forest stand was typical of many unmanaged pine stands in Arkansas, which have developed a dense hardwood midstory. Before thinning, the loblolly pine basal area averaged 27 m^2 /ha, and the hardwood basal area averaged 8 m^2/ha. Most hardwoods formed a uniform midstory with occasional individuals extending into the loblolly pine canopy. The hardwood component was principally willow and water oak (*Quercus phellos* and *Q. nigra*, respectively) with lesser amounts of southern red oak (*Q. falcata*) and sweetgum (*Liquidambar styraciflua*). Stem quality of the loblolly pine component was sometimes poor because of past damage from ice storms and stem cankers. Some of the hardwood stems were hollow or had other obvious stem defects.

Study Design.--Twenty-seven circular, 0.08-ha plots were established with a 10-m isolation strip around each, creating overall plots of 0.21 ha. Systematically located within each 0.08-ha plot were 25 (1 x 1m) subplots. Treatments reduced the overstory basal area to three levels for loblolly pine (15, 18, and 21 m^2/ha in trees ≥ 9.1 cm in diameter at breast height [d.b.h.]) and three levels for hardwoods (0, 3.5, and 7 m^2/ha). Treatments were randomly assigned as much as possible in a randomized block design with three blocks. Some plots, especially those with the highest level of hardwood retention, were assigned to meet specific targets.

The pine component of each plot was harvested as a free thinning. Most of the thinned trees were below the stand's mean d.b.h., but a few low quality dominant and codominants were thinned. Thinning of the hardwood component favored retention of the larger and better quality oaks. The plots and their adjoining isolation strips were thinned to the same basal areas. The areas between the combined plots and isolation strips were thinned to 18 m^2/ha of pine basal area and a component of desirable hardwoods.

All trees were harvested as pulpwood in 1.5-m bolts to minimize damage to the residual stand. Logging began in fall of 1988 but was terminated during the early winter because of wet soil conditions. Loblolly pine thinning was virtually completed by late spring of 1989, but unusually wet weather during the summer prevented completion of the hardwood thinning until late summer of 1989. Thus, logging continued intermittently for about 1 year with the pine component being mostly thinned before the 1989 growing season and the hardwoods being thinned at the end of the 1989 growing season. During late winter and early spring of 1990, all sub-merchantable hardwoods ≥ 2.5 cm d.b.h. were killed with stem-injected herbicides.

Percent cover before thinning and 2 and 4 years after thinning was ocularly estimated (Mueller-Dombois and Ellenberg, 1974) for seven preferred bobwhite quail food plants less than 1 m in height using the 25 subplots on each plot. Species included American beautyberry (*Callicarpa americana*), blackberry (*Rubus* spp.), tick trefoil (*Desmodium* spp.), lespedeza (*Lespedeza* spp.), panic grass (*Panicum* spp.), yellow wood sorrel (*Oxalis stricta*), and three-seeded mercury (*Acalypha* spp.). Mean percent cover was calculated for each species by treatment plot and year after thinning. An inventory was conducted after completion of thinning to determine overstory basal area. Canopy cover of the overstory was determined at each subplot using a spherical densiometer. Photosynthetically active radiation (light intensity) was determined at a height of 1.4 m on 39 temporary points systematically located within each plot during clear sky conditions on 31 July 1991 and 25 July 1993 using a sunfleck ceptometer. All measurements were taken within ± 1.5 hr of solar noon. Measurements also were taken in full sunlight so that relative percent light intensity of full sunlight could be calculated.

Data Analysis.--The basal area of individual plots varied within a treatment class because of (1) tree mortality from logging damage and natural causes, (2) growth during study installation, and (3) the inability to precisely control basal areas on small plots. After study installation, basal areas varied by a mean of 1.5 m^2/ha within treatment classes for both pines and hardwoods. Because of this variation, data were analyzed using regression. This allowed using the actual basal area of each plot rather than its class designation. Several candidate equations were evaluated for use in analyzing the data. Based on residual plots and fit indices, we selected the following form:

$$Y = \exp(b_0 + b_1T + b_2P + b_3H)$$

where Y is the specific response variable, T is the time after thinning in years, P and H are the residual pine and hardwood basal areas, respectively, and the b_i's are coefficients to be determined. Coefficients were calculated by nonlinear least squared regression using the SAS procedure MODEL (SAS Institute, 1988). Data for fitting our equation were the mean percent cover of individual species on each of the 27 plots evaluated at 2 and 4 years after thinning. This provided a total of 54 observations for each plant species. Variables were eliminated from the full model if their coefficient did not significantly differ from zero at a probability level of $P \leq 0.10$. The fit index reported for these equations is analogous to the coefficient of determination.

Results

Before thinning, coverage of American beautyberry, blackberry, and tick trefoil averaged less than 1% across our study area (Fig. 1). Lespedeza, panic grass, yellow wood sorrel, and three-seeded mercury were not observed prior to thinning. Positive regression coefficients (Table1) demonstrated that the woody plants, American beautyberry and blackberry, increased with time (Fig. 1) through four years. The herbaceous plants tick trefoil and panic grass were negatively influenced by time as indicated by their negative regression coefficients. However, the other herbaceous plants, lespedeza, yellow wood sorrel, and three-seeded mercury, were not influenced significantly by time since thinning. Blackberry and panic grass were influenced negatively by increasing pine basal area; all other plant species were not effected. Three-seeded mercury was the only plant species studied that was not negatively influenced by increasing hardwood basal area. Canopy cover and relative light intensity demonstrated an inverse relationship, with light intensity decreasing as pine and hardwood canopy cover increased (Fig. 2). Increases in canopy cover from 2 - 4 years were greatest for plots with the lowest basal areas.

Table 1. Regression coefficients and associated statistics for determining percent cover of plant species important as food sources for bobwhite quail from the number of years after stand thinning, residual pine basal area, and hardwood basal area in a thinned 35-year-old loblolly pine-hardwood stand in southeastern Arkansas. Also shown are regression coefficients for determining canopy cover and relative light intensity.

Response variable	Regression coefficients[1]				Mean	RMSE	Fit
	b_0	b_1	b_2	b_3	coverage[2]		index
Plant species							
Blackberry	3.320	0.426	-0.137	-0.346	3.90	2.12	0.82
Panic grass	4.600	-0.338	-0.104	-0.133	3.66	3.08	0.34
American beautyberry	0.813	0.225	ns	-0.158	2.80	2.68	0.23
Lespedeza	-0.296	ns	ns	-0.271	0.37	0.53	0.21
Yellow wood sorrel	-0.648	ns	ns	-0.200	0.29	0.27	0.30
Tick trefoil	ns	-0.334	ns	-0.149	0.25	0.38	0.13
Three-seeded mercury	ns	ns	ns	ns	0.14	---	---
Canopy cover	4.100	0.037	0.010	0.021	88.30	5.89	0.59
Light intensity	5.276	-0.057	-0.080	-0.155	23.10	4.60	0.87

[1]The equation is $Y = \exp(b_0 + b_1T + b_2P + b_3H)$ where Y is the specified response variable, T is the time after thinning in years, P and H are the residual pine and hardwood basal areas, respectively, in m^2/ha after thinning. Shown coefficients were significant at $P \leq 0.10$. Non-significant coefficients are indicated by ns.
[2]Mean percent cover of individual species calculated from 27 plots evaluated at 2 and 4 years after thinning. This provided a total of 54 observations for each plant species.

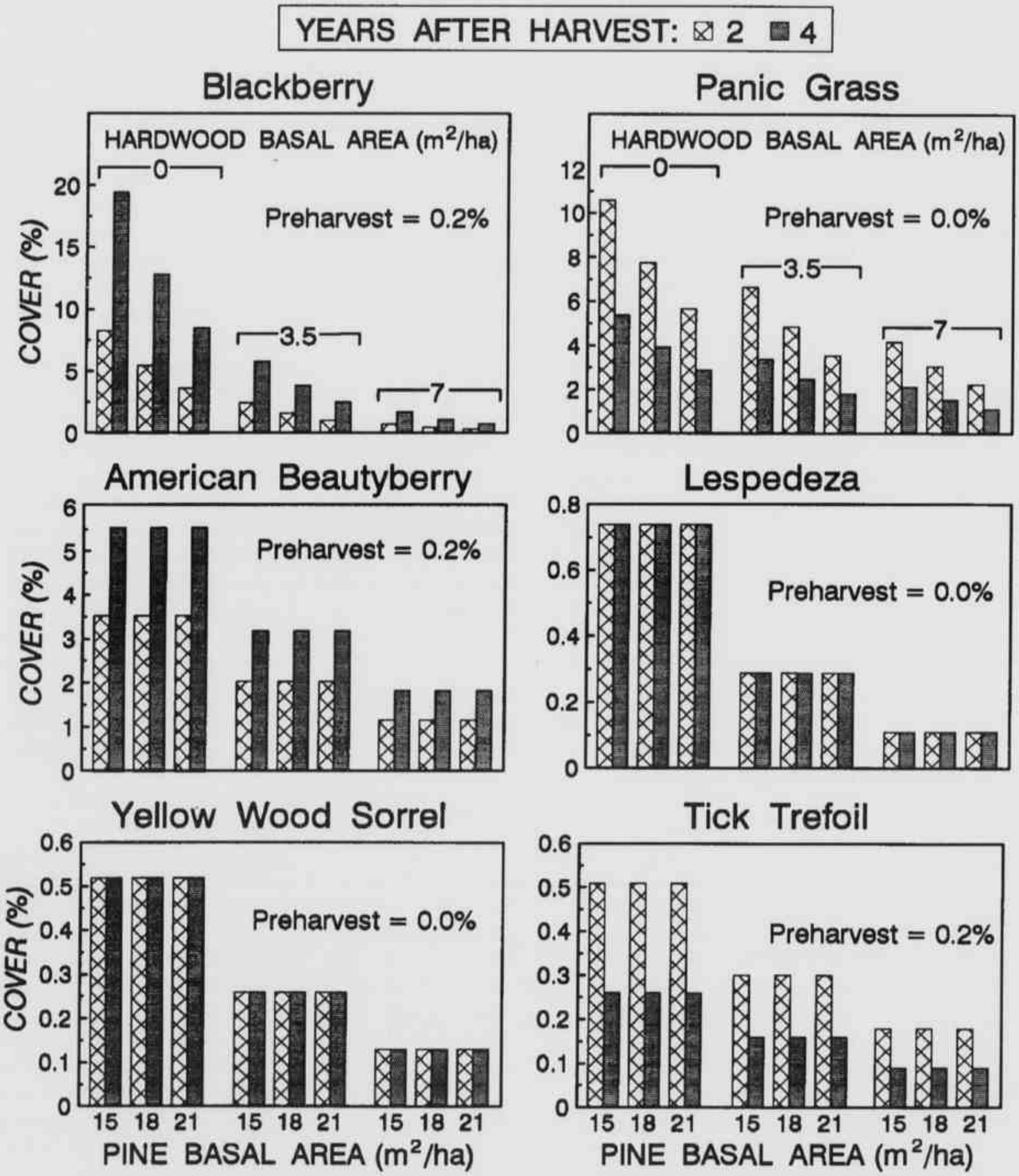

Fig. 1. Effects of residual pine and hardwood basal areas on selected bobwhite quail food 2 and 4 years after thinning a 35-year-old pine-hardwood stand in southeastern Arkansas. Percent covers are values calculated from their appropriate equation in Table 1.

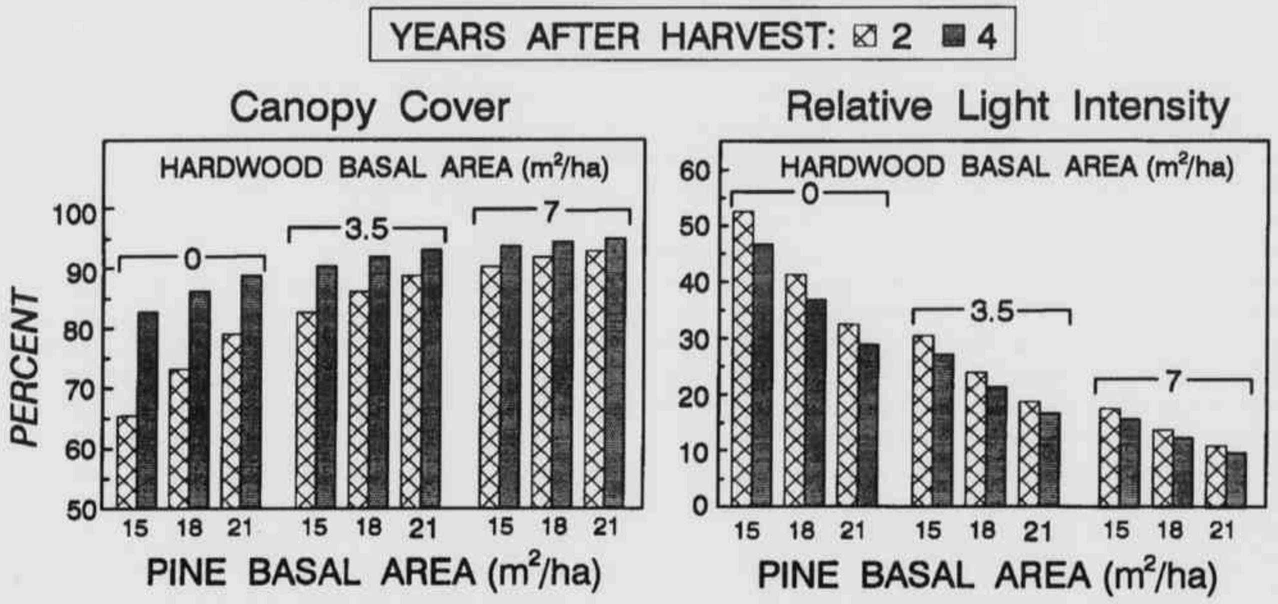

Fig. 2. Effects of residual pine and hardwood basal areas on overstory canopy cover and relative light intensity 2 and 4 years after thinning a 35-year-old pine-hardwood stand in southeastern Arkansas. Percent values were calculated from their appropriate equation in Table 1.

Discussion

Thinning is a necessary practice for improving bobwhite quail habitat on unmanaged and overstocked forested lands. Thinning reduces the overstory canopy, increases light intensity reaching the forest floor, reduces competition for nutrients and water, and releases understory vegetation for growth. For bobwhite quail, thinning requires removal of enough basal area to open up the canopy and allow increased vegetative growth in the understory while retaining some canopy to deter excessive growth of woody understory vegetation and its associated litter (Landers and Mueller, 1986). Our study demonstrated that as basal area was reduced there was a corresponding increase in understory vegetative growth and a faster rate of woody plants replacing some of the herbaceous plants utilized by bobwhite quail as food. However, some bobwhite quail plant foods were not as readily displaced by increasing woody vegetation. Therefore, we can infer that a moderate level of pine and hardwood thinning on this study site will favor bobwhite quail. Bobwhite quail are less able to forage successfully on seeds and soft mast that drop to the forest floor and become covered by litter. This situation would occur more often in stands retaining a high total basal area. Also, the ability of bobwhite quail to catch insects is inhibited by thick litter.

Operational thinnings in forested stands similar to our research area are conducted every 5 - 10 years. However, repeated thinnings on a shorter interval, less than 5 years, may be required to keep panic grass and tick trefoil at peak levels in forested stands in southeastern Arkansas. But, thinning at such a short interval may have a negative impact on American beautyberry and blackberry, as their peak coverage appears to have not been reached by the end of this study. A similar relationship between decreasing herbaceous vegetation and increasing woody plants with time has been reported elsewhere (Blair, 1971; Masters et al., 1993). Thinning and its associated disturbance was required before lespedeza, panic grass, yellow wood sorrel, and three-seeded mercury appeared in our stand because these are early successional stage plants. After initial establishment, the lack of change with time of lespedeza, yellow wood sorrel, and three-seeded mercury suggests that these plants may have been influenced more by ground disturbance from logging than by increasing canopy cover as retained trees grew.

The greater coverage of vegetation on treatment areas retaining less total basal area demonstrates that bobwhite quail habitat can be improved through thinning. All plant species in our study benefited from a reduction of the hardwood basal area with the exception of three-seeded mercury. This response of understory vegetation to thinning has been observed by others in the southeastern United States

(Masters et al., 1993; Wigley et al., 1989). The mast production of midstory hardwoods is generally low (Drake, 1991). Therefore, the removal of these hardwoods will help improve bobwhite quail habitat by increasing the light intensity reaching the forest floor and reducing the leaf litter produced. Hardwoods have been demonstrated to produce twice as much shading as pines of the same height and diameter (Tappe et al., 1993). Reduction of pine basal area increased plant coverage for some species. Panic grass and blackberry in particular appeared to have been negatively influenced by increasing amounts of pine basal area.

Our study indicates that thinning a forest stand improves bobwhite quail habitat by increasing the amount of light reaching the understory, which promotes plant growth of species utilized by bobwhite quail as food sources. However, with time, many herbaceous plants are replaced by woody plants. Hardwood retention appears to influence understory plant growth more than retained pines.

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