light counts were used to determine alfalfa loss/deer-night. Mean air-dry alfalfa loss/deer-night was 2.2 kg. From these results and using our seasonal and night-long deer counts, a simple method to estimate crop loss in alfalfa was developed. Deer in alfalfa fields are counted weekly using spotlight, horn, and binoculars between 1–2 hours after sunset. Total deer-nights are calculated and alfalfa loss is determined using 1.3–3.1 kg/deer-night.

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Received 8 March 1992.
Accepted 4 March 1993.
Associate Editor: Swihart.

***Wildl. Soc. Bull.* 21:401–411, 1993**

EFFECTS OF TIMBER HARVEST AND PRESCRIBED FIRE ON WHITE-TAILED DEER FORAGE PRODUCTION

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The standing crop of winter and late summer forage in the Ouachita Mountains of eastern Oklahoma and western Arkansas often is low and may be a factor that limits white-tailed deer (*Odocoileus virginianus*) populations (Segelquist and Pennington 1968, Fenwood et al. 1984). Mortality and productivity rates of white-tailed deer have been related to mast failure and may be compounded by the lack of evergreen browse in winter (Segelquist and Pennington 1968; Segelquist et al. 1969, 1972; Logan 1972; Fenwood et al. 1984). Consequently deer use of food plots has increased during years of mast shortfall, and winter mortality has been reduced in enclosures with for-

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est openings (Segelquist 1974:143, Segelquist and Rogers 1974).

Observations that forest openings are readily used by deer in the Ozark Highlands have led to increased timber harvest and prescribed fire on wildlife management areas in Oklahoma to improve habitat conditions for deer. Forest openings created through commercial timber harvest have been maintained in early successional stages using prescribed fire to provide forage. Forage response to regeneration clearcutting and hazard reduction burning has been studied across the Southeast (e.g., Hebb 1971, Stransky and Halls 1978, Wood 1988, Locascio et al. 1990). However, similar information on response of forage to techniques that maintain early successional stages does not exist for the low-fertility soils that characterize much of the commercial forests in the Ouachita Mountains.

The primary objective of our study was to examine production response of vegetation to a range of techniques for initiating and maintaining early successional stages in the Ouachita Mountains. We compared the effectiveness of timber harvest combined with 5 prescribed fire regimes, to regeneration clearcuts and understory rough reduction burns (prescribed burns to reduce fuel loads) as techniques for improving deer browse production on 1 wildlife management area. We also determined the fire frequency necessary to maintain forest openings in early secondary succession.

STUDY AREA

The 29-ha study area was located within the Forest Habitat Research Area (FHRA) on the 7,395-ha Pushmataha Wildlife Management Area (WMA), Pushmataha County, Oklahoma (34°32'N, 95°21'W). The Pushmataha WMA lies in mountainous terrain along the western edge of the Ouachita Mountain physiographic region. The climate was semihumid to humid with hot summers and mild winters. Summer maximum temperatures were >33 C. Prevailing winds were from the south (Bain and Watterson 1979:1). Annual rainfall was 106–188 cm between 1978 and 1990, based on an October–September water-year. Late summers were dry; rainfall in July and August averaged 15 cm (Dep. For., Oklahoma State Univ., Stillwater, unpubl. data, 1991; Masters 1991*b*:75).

Soils belonged to the Carnasaw-Pirum-Clebit association with areas of rock outcrop. Soils developed from sandstone and shales and were thin and drought prone. The surface layer was 0–30 cm deep, and texture was stony fine sandy loam (Bain and Watterson 1979:9). The FHRA was situated near a ridgetop approximately 335 m in elevation on a southeastern aspect with a 5–15% slope.

The FHRA overstory was dominated by post oak (*Quercus stellata*), shortleaf pine (*Pinus echinata*), blackjack oak (*Q. marilandica*), and mockernut hickory (*Carya tomentosa*). Shortleaf pine composed 55% of the basal area before treatment. Overstory pines were 40–90 years old. Overstory hardwoods were 52–156 years old.

Common woody understory species included farkleberry (*Vaccinium arboreum*), poison-ivy (*Toxicodendron radicans*), and greenbriars (*Smilax* spp.). Predominant herbaceous plants were little bluestem (*Andropogon scoparius*), big bluestem (*A. gerardi*), panicums (*Panicum* spp.), and sedges (*Carex* spp., *Scleria* spp., *Rhynchospora* sp.) (Masters 1991*a*).

The Pushmataha WMA was established as a game refuge following acquisition of several tracts in 1946, 1949, and 1950 by the Oklahoma Department of Wildlife Conservation (Okla. Game and Fish Dep. 1950: 26). Before acquisition, the Pushmataha WMA was grazed by cattle, selectively harvested, and subject to burning at 1- to 3-year intervals (Masters 1991*b*:78). Deer populations reached an estimated 9.4/km^2 (SE = 1.4) by 1973, but browse lines became apparent around food plots and deer numbers declined to 5.3/km^2 (SE = 0.2) by 1978. From 1986 to 1990 the estimated deer population averaged 8.7/km^2 (SE = 0.4). Approximately 0.2 elk (*Cervus elaphus*)/km^2 were on the Pushmataha WMA in 1990 (Masters 1991*b*:78–84).

Forest opening coverage on the Pushmataha WMA was increased from 4% in 1973 to 28% in 1990 through an aggressive timber management program. Forest openings were burned at 3- to 5-year intervals to keep them in early stages of secondary succession. Until this study began, the FHRA had been protected from livestock grazing, logging, and fire since acquisition (Masters 1991*b*:78).

METHODS

Application of Treatments

Beginning in summer 1984, 9 treatments were applied to 23 1.2- to 1.6-ha units in a completely randomized experimental design (Table 1). During summer 1984, merchantable pine timber was harvested in assigned treatments, and hardwoods were selectively thinned by single stem injection using 2,4-D to an approximate basal area of 9 m^2/ha. Prescribed strip-head fires were applied on appropriate units in winter 1985 and in succeeding years at 1-, 2-, 3-, and 4-year intervals. Fireline intensity of March 1988 burns ranged from 628 to 903 kW/m (Masters 1991*b*:280). The clearcut site preparation treatment included shearing, raking, and windrowing of logging debris with a site preparation burn conducted during summer 1985. After contour ripping, genetically improved loblolly pine (*P. taeda*) seedlings were planted on a 2.1- × 2.4-m spacing in early April 1986.

Sampling Methods

We sampled vegetation in September and October of each year, coinciding with a critical period of nutritional stress for deer in the Ouachita Mountains (Fenwood et al. 1984). On each treatment unit, we established 10 permanent plots at 19.8-m intervals on 2 randomly located lines perpendicular to the contour. To avoid bias caused by influences from adjacent treatment units, we did not sample within 19.8 m of any edge (Mueller-Dombois and Ellenberg 1974:123).

Basal Area and Canopy Cover.—Basal area of overstory vegetation was quantified each year using the variable radius plot method (Avery 1967:165–168). Basal areas of stems ≥5 cm diameter at breast height (dbh) were measured with a 10-factor wedge prism at each permanent plot location. We conducted baseline sampling before cultural treatment application in 1983. Overstory canopy cover was determined with a 5-point grid in a sighting tube with vertical and horizontal levels at plot center and cardinal points at 2 and 4 m from each permanent plot location (Mueller-Dombois and Ellenberg 1974:89).

Standing Crop.—We measured herbaceous and woody standing crop by the harvest method (Cook and Stubbendieck 1986:52–53) in the first 2 weeks of September 1986–1990 within 0.5- × 0.5-m (0.25 m^2) quadrats. Current year's growth of vegetation was clipped to <2.5 cm height and hand separated into sedge, legume, panicum (primarily those that form winter rosettes), other grasses, forb, and woody categories. Woody growth was clipped to ≤1.4 m. Litter was collected down to mineral soil and included dead grass, leaves, bark fragments, and twigs <2.5 cm diameter. Samples were dried to constant weight at 70 C in a forced-air oven. Size and number of quadrats were determined by Cain and Castro's (1959:167–174) minimal area concept to derive species-group area curves. Subsample sizes ranged from 5 to 15/experimental unit.

Previous work with enclosures on sites adjacent to the FHRA suggested that deer densities >8/km^2 may affect forage standing crop estimates in unenclosed areas (T. Silker, Oklahoma State Univ., Stillwater, unpubl. data). Deer density estimates on our study area from 1985 to 1990 were ≥8/km^2 (Masters 1991*b*:83, 191). Effects of cervid herbivory on standing crop estimates were assessed by harvesting paired plots in and out of movable cages (area = 0.4 m^2, ht = 0.7 m) along randomly located transects in 1987–1989 (Oosting 1956: 39, Cook and Stubbendieck 1986:56). Cages were moved to new locations each March.

Data Analysis

We used the Kruskal-Wallis nonparametric test to test for treatment differences ($P < 0.05$) in standing crop, basal area, and canopy cover estimates between treatments (SAS Inst. Inc. 1985:651). When data were analyzed across years, the year × unit × treatment Type III mean square was used as the error term. Multiple comparisons between mean ranks were made with Tukey's test with $\alpha = 0.05$ (Conover and Iman 1981). Pearson correlation coefficients were calculated to examine the relationship between total standing crop and basal area, canopy cover, and litter accumulation (SAS Inst. Inc. 1988:126).

We determined effects of herbivory on standing crop with a 2-tailed paired *t*-test to compare caged and uncaged standing crop estimates (Steel and Torrie 1980: 90; SAS Inst. Inc. 1985:799, 1988:235). When differences between uncaged and caged plots were not significant ($P > 0.05$), plots were combined for analysis of treatment effects.

RESULTS

Cost of Treatments

Herbicide and labor costs for thinning of hardwoods totaled \$67/ha for harvested and thinned treatments. Prescribed burning costs, including fireguards, averaged \$24/ha, which was higher than the \$15/ha typical for eastern Oklahoma (Thompson et al. 1991). The experimental design necessitated fireguards around each experimental unit and inflated the cost/ha. The cost of site preparation on the CCSP (see Table 1 for treatment descriptions) treatment was \$510/ha and included the cost of replanting. All treatments except the control and RRB generated income from the sale of pine timber. The HT and CCSP should generate additional revenue in the future. For comparison, the annualized cost of food plot maintenance on the Pushmataha WMA was \$212/ha (includes equipment cost and maintenance). The cost of food plots did not include the 1-time clearing cost of \$371/ha.

Basal Area and Canopy Cover

In 1983, the average basal area on all experimental units was 25.3 m^2/ha (SE = 0.5). Basal area of the overstory was reduced by 61–80% ($\bar{x}$ = 8.2 m^2/ha, SE = 0.7; $F = 5.82$; 6,11 df; $P = 0.0060$) on all harvested and thinned treatments in 1984. After the initial treatment in 1984 and 1985, basal area changed little and

Table 1. Percent canopy cover after summer 1984 timber harvest and periodic prescribed fire on oak-pine sites in the Ouachita Mountains, Oklahoma, from 1985 to 1990.[a]

	Treatment[b,c]									
	Control	RRB	HNT1	HT	HT4	HT3	HT2	HT1	CCSP	
Year	$\bar{x}$ (SE) (n = 3)	$\bar{x}$ (SE) (n = 3)	$\bar{x}$ (SE) (n = 3)	$\bar{x}$ (SE) (n = 1)	$\bar{x}$ (SE) (n = 3)	$\bar{x}$ (SE) (n = 2)	$\bar{x}$ (SE) (n = 3)	$\bar{x}$ (SE) (n = 2)	$\bar{x}$ (SE) (n = 3)	$P > F$
1985	77 (2.4)a	67 (4.3)ab		23 ( )abc	7 (4.2)bc	6 (4.2)bc	14 (6.3)abc		4 (4.1)c	0.0030
1986	82 (1.5)a	73 (5.8)ab	30 (7.8)abcd	32 ( )abc	9 (4.5)cde	7 (4.4)cde	15 (7.3)bcde	6 (5.7)de	0 (0.0)e	0.0001
1987	86 (3.5)a	79 (4.2)ab	31 (8.3)abc	33 ( )abc	12 (6.4)cd	11 (6.7)bcd	19 (9.0)abcd	5 (4.2)cd	0 (0.0)d	0.0001
1988	85 (2.9)a	84 (4.0)a	35 (6.9)ab	29 ( )ab	11 (5.7)bc	7 (3.8)bc	19 (7.6) abc	8 (6.2)bc	0 (0.0)c	0.0001
1989	85 (0.6)a	80 (4.5)ab	31 (6.2)abc	39 ( )abc	11 (5.3)cd	9 (5.3)cd	17 (5.4)bcd	8 (5.4)cd	2 (0.9)d	0.0001
1990	87 (1.6)a	78 (3.7)ab	31 (6.0)abc	45 ( )abc	12 (6.3)bc	10 (7.0)bc	19 (7.1)abc	8 (5.0)c	14 (0.4)bc	0.0009

[a] Row means followed by the same letter within category did not differ ($P > 0.05$).

[b] Control = no treatment; RRB = rough reduction winter burn 4-year cycle (1985, 1989); HNT1 = harvest pine timber, no thinning of hardwoods, winter burn annually; HT = harvest pine timber, thin hardwoods, no burn; HT4 = harvest pine timber, thin hardwoods, winter burn 4-year cycle (1985, 1989); HT3 = harvest pine timber, thin hardwoods, winter burn 3-year cycle (1985, 1988); HT2 = harvest pine timber, thin hardwoods, winter burn 2-year cycle (1985, 1987, 1989); HT1 = harvest pine timber, thin hardwoods, winter burn annually; CCSP = clearcut, summer site preparation burn (1985).

Columns without numbers represent missing data points, or in the case of SE only 1 replication was included for that treatment.

canopy cover changed only on CCSP treatments. Canopy cover was lower ($F = 11.48$; 8,13 df; $P = 0.0001$) on harvested, thinned, burned, and CCSP treatments than on unharvested treatments by 1989 (Table 1). Canopy cover increased from 0% (SE = 0.0) in 1986 to 14% (SE = 0.4) on CCSP as planted loblolly pine seedlings entered the sapling stage by 1990 (Table 1).

Standing Crop

Cervid herbivory had no effect on standing crop comparisons. Of 189 standing crop paired comparisons (9 treatments × 7 species groups × 3 yr) between caged and uncaged plots, only 2 were different ($P < 0.05$). We would expect 9 differences from random error alone.

Grass standing crop averaged 35 times greater ($F = 34.18$; 8,56 df; $P = 0.0001$) on HT1 than on control treatments (3,237 vs. 95 kg/ha) over all years (Table 2). Little bluestem, big bluestem, and Indiangrass (*Sorghastrum nutans*) contributed the most to grass standing crop, which increased on harvested and burned treatments in the year after a winter burn and then gradually declined as litter accumulated.

Panicum standing crop increased after overstory removal but differences among treatments were dependent on burn synchrony among treatments (Table 2). On harvested and burned treatments, standing crop of panicums declined the first growing season after a burn but increased in the second growing season. In 1989, when HNT1, HT1, HT2, HT4, and RRB were burned, panicum standing crop did not differ ($F = 2.64$; 8,13 df; $P = 0.0580$) among treatments. Panicum standing crop on the CCSP was highest 3 years postharvest and later declined as tallgrasses and canopy cover of planted pines increased ($F = 5.65$; 8,14 df; $P = 0.0025$).

Average sedge standing crop over all years was higher on harvested and burned sites ($F = 12.10$; 8,56 df; $P = 0.0001$) than on unharvested treatments (Table 2). Sedge standing crop estimates were similar among harvested and burned treatments regardless of burning regime. On the CCSP treatment, sedge standing crop was greatest the fourth year after timber harvest.

Annual or biennial burning intervals favored production of legumes. Legumes were often higher ($P < 0.05$) the first growing season after a burn on harvested treatments than controls (Table 2). Forbs were variable in their response to timber harvest and fire depending on the year posttreatment. Clearcutting and summer site preparation burns initially increased forb and legume production, but as tallgrasses and planted pines increased in percent cover, forb and legume production declined.

Standing crop of current annual growth of woody plants did not differ among treatments until 1989 ($F = 3.37$; 8,13 df; $P = 0.0256$), the fifth growing season after timber harvest. Less-frequent burning intervals favored woody plant production. On harvested and burned treatments, the primary woody species were flameleaf sumac (*Rhus copallina*), dewberries (*Rubus* spp.), and post oak sprouts. Flameleaf sumac was a minor (<1% cover) component on unburned or unharvested treatments in all years.

Total standing crop of forage was consistently higher ($P < 0.05$) on HT1, HT2, HT3, and HT4 than untreated controls and RRB treatments (Table 2). Overall total standing crop was up to 25 times greater on harvested and burned treatments than control treatments (4,234 vs. 156 kg/ha in 1990) ($F = 13.63$; 8,13 df; $P = 0.0001$). Rough reduction burns increased forage standing crop 1.4 times compared to untreated controls (405 vs. 171 kg/ha for all years). Total standing crop was negatively related to basal area ($r = -0.887$, $P = 0.0001$, $n = 23$), canopy cover ($r = -0.900$, $P = 0.0001$, $n = 23$), and litter accumulation ($r = -0.799$, $P = 0.0001$, $n = 23$). On burned treatments, standing crop generally increased in the year following a burn but declined in subsequent years. Grasses were the primary component in harvested and burned treatments, except for the HT4 treatment, where current annual woody growth was important in latter years.

DISCUSSION

Vegetation responses on harvested and burned sites were similar to those reported by Hebb (1971) for clearcutting. Successional stages after harvest were (1) disturbed site with pretreatment understory ground cover; (2) profusion of grasses and annual forbs; (3) increase in perennial forbs, shrubs, and grasses, and decrease in annuals; and (4) increases in shrubs and grasses and declines in forbs in the absence of periodic prescribed fire.

Chronosequences of vegetation on harvested sites subjected to fire at varying frequencies were similar to the response of burned mesic tallgrass prairie (Anderson and Brown 1986). Longer fire intervals allowed woody species to increase whereas more frequent burns favored an increase in tallgrasses (Bragg and Hulbert 1976, Petranka and McPherson 1979).

Timber harvest and fire increased forage standing crop on oak-pine sites in the Ouachita Mountains. The relationship between forage production and overstory is curvilinear with forage production negatively related to presence of overstory (e.g., Jameson 1967, Wolters 1973, Blair and Enghardt 1976, Fenwood et al. 1984). Fire reduces standing dead herbaceous vegetation and litter accumulation that can suppress herbaceous vegetation growth (Hulbert 1988). The combination of overstory removal and burning may initiate earlier growth and greater production as a result of warmer soil temperatures, increased nitrogen availability, and increased surface light intensity (Peet et al. 1975, Knapp 1984, Hulbert 1988, Svejcar and Browning 1988).

Total standing crop averaged across years on HNT1, HT2, HT3, and HT4 did not differ from CCSP. These treatments generally had higher total standing crop than HT and lower

Table 2. Early September standing crop (kg/ha) in response to 1984 timber harvest and periodic prescribed fire on oak-pine sites in the Ouachita Mountains, Oklahoma, from 1987 to 1990.[a]

Plant group, treatment[c,d]	Year[b] 1987 x̄ (SE)	1988 x̄ (SE)	1989 x̄ (SE)	1990 x̄ (SE)	All years x̄ (SE)
Grass					
Control	105 (80)d	61 (18)c	108 (64)	104 (21)c	95 (23)d
RRB	132 (47)cd	188 (92)bc	326 (162)	248 (201)bc	224 (63)d
HNT1	2,396 (875)ab	1,499 (598)abc	1,985 (765)	923 (170)abc	1,701 (326)bc
HT	732 ( )bcd	609 ( )bc	1,238 ( )	550 ( )bc	782 (157)c
HT4	1,452 (423)abc	1,132 (384)abc	2,970 (1,192)	1,972 (454)ab	1,882 (364)b
HT3	1,817 (367)ab	1,946 (578)ab	3,037 (891)	883(541)abc	1,921 (373)b
HT2	1,202 (203)abcd	1,258 (200)abc	2,915 (459)	1,444 (262)abc	1,705 (248)b
HT1	3,572 (500)a	2,458 (242)a	3,257 (253)	3,660 (284)a	3,237 (220)a
CCSP	1,007 (57)abcd	1,609 (184)ab	2,977 (217)	868 (296)abc	1,301 (243)bc
Panicum					
Control	25 (8)b	8 (3)b	7 (3)	8 (4)	12 (3)d
RRB	30 (19)b	23 (4)ab	19 (5)	29 (10)	25 (5)cd
HNT1	57 (24)b	126 (76)ab	171 (108)	108 (76)	116 (35)bc
HT	236 ( )ab	212 ( )ab	111 ( )	82 ( )	160 (38)ab
HT4	366 (64)ab	195 (20)ab	112 (65)	230 (38)	226 (35)ab
HT3	259 (88)ab	235 (81)ab	93 (36)	113 (11)	175 (36)ab
HT2	379 (102)ab	439 (126)a	238 (101)	247 (107)	326 (53)a
HT1	230 (202)ab	48 (32)ab	59 (49)	32 (4)	92 (50)bcd
CCSP	578 (79)a	400 (91)a	364 (180)	164 (152)	374 (58)a
Sedge					
Control	3 (1)	7 (4)	5 (1)	5 (3)b	5 (1)d
RRB	22 (10)	2 (2)	5 (5)	12 (6)b	10 (4)cd
HNT1	38 (10)	24 (16)	121 (44)	43 (20)ab	57 (16)abc
HT	4 ( )	17 ( )	72 ( )	28 ( )ab	30 (15)bcd
HT4	412 (178)	134 (43)	67 (21)	107 (53)ab	180 (58)a
HT3	13 (0)	143 (129)	88 (88)	87 (41)ab	83 (35)abc
HT2	137 (70)	161 (44)	166 (48)	77 (17)ab	135 (23)a
HT1	26 (26)	123 (13)	203 (93)	196 (20)a	137 (33)ab
CCSP	17 (9)	263 (206)	37 (3)	38 (18)ab	91 (49)abc
Legume					
Control	4 (0)bc	8 (4)c	6 (2)b	9 (1)	7 (1)c
RRB	12 (9)bc	11 (4)bc	31 (17)ab	22 (15)	19 (6)c
HNT1	28 (11)abc	70 (20)abc	100 (34)ab	50 (18)	62 (12)ab
HT	1 ( )c	28 ( )abc	35 ( )ab	54 ( )	30 (11)bc
HT4	67 (37)abc	12 (3)bc	197 (87)ab	46 (17)	81 (29)ab
HT3	139 (25)a	75 (15)abc	211 (32)a	62 (10)	122 (24)a
HT2	109 (16)ab	125 (6)a	207 (34)a	55 (22)	124 (19)a
HT1	67 (27)abc	212 (132)ab	204 (122)a	100 (72)	146 (44)a
CCSP	104 (27)ab	94 (44)abc	54 (16)ab	10 (2)	67 (14)ab
Forbs					
Control	11 (6)	6 (4)b	11 (3)	12 (4)	10 (2)c
RRB	20 (10)	14 (11)ab	21 (5)	34 (11)	22 (5)bc
HNT1	349 (192)	71 (10)ab	95 (32)	195 (72)	178 (55)a
HT	151 ( )	13 ( )ab	137 ( )	14 ( )	79 (38)ab
HT4	121 (47)	52 (22)ab	67 (28)	39 (6)	70 (16)ab
HT3	220 (203)	164 (8)a	218 (175)	17 (5)	155 (59)a
HT2	302 (127)	85 (30)ab	318 (139)	81 (34)	197 (54)a
HT1	144 (62)	358 (316)ab	176 (122)	88 (56)	191 (76)a
CCSP	1,001 (820)	192 (67)ab	145 (121)	90 (82)	577 (212)a

Table 2. Continued.

Plant group, treatment[c,d]	Year[b] 1987 $\bar{x}$ (SE)	1988 $\bar{x}$ (SE)	1989 $\bar{x}$ (SE)	1990 $\bar{x}$ (SE)	All years $\bar{x}$ (SE)
Woody					
Control	18 (4)	52 (15)	18 (5)b	18 (5)b	27 (6)c
RRB	110 (44)	35 (26)	125 (49)ab	136 (45)ab	102 (21)bc
HNT1	379 (204)	138 (73)	242 (98)ab	77 (43)ab	209 (62)abc
HT	245 ( )	281 ( )	168 ( )ab	630 ( )a	331 (102)ab
HT4	472 (225)	220 (149)	973 (32)a	880 (187)a	636 (116)a
HT3	885 (1)	503 (5)	328 (98)ab	218 (26)ab	483 (98)ab
HT2	408 (234)	288 (159)	643 (312)ab	307 (106)ab	411 (102)ab
HT1	264 (88)	296 (294)	561 (9)ab	158 (146)ab	320 (85)abc
CCSP	155 (103)	633 (219)	226 (222)ab	560 (480)ab	346 (101)abc
Total					
Control	196 (60)c	143 (31)b	188 (38)	156 (15)e	171 (81)e
RRB	336 (116)bc	272 (106)b	531 (217)	482 (252)de	405 (85)de
HNT1	3,246 (1,057)abc	1,927 (672)ab	2,715 (858)	1,397 (123)cde	2,321 (389)bc
HT	1,369 ( )abc	1,161 ( )ab	1,762 ( )	1,358 ( )bcde	1,413 (126)cd
HT4	2,891 (234)abc	1,745 (494)ab	4,386 (1,269)	3,274 (245)ab	3,074 (413)ab
HT3	3,333 (102)ab	3,066 (531)a	3,975 (1,257)	1,380 (458)bcde	2,939 (453)ab
HT2	2,537 (422)abc	2,357 (127)ab	4,487 (349)	1,948 (241)abc	2,832 (323)b
HT1	4,303 (449)a	3,495 (965)a	4,459 (531)	4,234 (574)a	4,123 (286)a
CCSP	2,939 (829)abc	3,191 (289)a	3,803 (759)	1,730 (30)abcd	2,772 (278)b

[a] Column means followed by the same letter or without letters within plant group did not differ ($P > 0.05$).
[b] In 1986 standing crop means (SE) on the CCSP were: grass = 457 (86), panicum = 290 (119), sedge = 63 (6), legume = 48 (14), forbs = 1,150 (124), woody = 187 (140), and total = 2,195 (263).
[c] Control = no treatment ($n = 3$); RRB = rough reduction winter burn 4-year cycle (1985, 1989) ($n = 3$); HNT1 = harvest pine timber, no thinning of hardwoods, winter burn annually (1985–1990) ($n = 3$); HT = harvest pine timber, thin hardwoods, no burn ($n = 1$); HT4 = harvest pine timber, thin hardwoods, winter burn 4-year cycle (1985, 1989) ($n = 3$); HT3 = harvest pine timber, thin hardwoods, winter burn 3-year cycle (1985, 1988) ($n = 2$); HT2 = harvest pine timber, thin hardwoods, winter burn 2-year cycle (1985, 1987, 1989) ($n = 3$); HT1 = harvest pine timber, thin hardwoods, winter burn annually (1985–1990) ($n = 2$); CCSP = clearcut, summer site preparation burn (1985) ($n = 3$).
[d] (SE) without numbers indicate that only 1 replication was included for that treatment.

total standing crop than HT1. However, production was declining on CCSP units and should continue to decline with canopy closure. Although their value for forage production may diminish as canopy cover increases, HT and CCSP treatments were important because they provided escape and screening cover for deer (Masters 1991*a*). The RRB treatment demonstrated a slight increase in standing crop of approximately the same magnitude described by Lay (1967).

Grass production composed most (≥60%) of the total standing crop relative to other species groups on harvested and burned treatments and until 1990 on the CCSP treatment. Panicums and other grasses are important forage for deer during late winter and early spring because they provide forage high in digestibility and nutrients during a period of nutritional stress (Short 1971, Lewis et al. 1982). However, fire-tolerant warm-season grasses such as little bluestem and big bluestem are considered poor deer forage during most of the year (Stransky and Harlow 1981).

Forbs were important in May and constituted up to 48% of deer diets in this month (Jenks et al. 1990:8). However, woody browse was the major constituent of deer diets (with heavy cattle stocking) in southeastern Oklahoma in all months except May (Jenks et al. 1990:8). Woody browse production increased with longer fire intervals or when fire was excluded. When hard mast was available in fall and winter, it composed the major portion of deer diets in the Ouachita Mountains (Fenwood et al. 1985).

MANAGEMENT IMPLICATIONS

Poor habitat quality has been implicated as a major limiting factor for deer on oak-pine sites (Segelquist and Pennington 1968, Fenwood et al. 1984). High forage quality was important for optimum growth and productivity of deer (Verme 1965, Ullrey et al. 1967). Timber harvest and prescribed fire increased forage quality and quantity in late summer and early fall, and plant species richness on our sites (Masters 1991*a*,*b*:148, 199). Deer diets consisted of higher quality forage when more diverse forage was available (Thill et al. 1990).

High-quality agricultural crops are generally grown in food plots for deer as a management technique (Segelquist and Rogers 1974). However, food plots are limited in distribution and abundance over many WMA's by maintenance costs, limited personnel, and time constraints. Food plots lack plant diversity, and forage availability may be seasonally limited depending on the crop planted.

Management of habitats by conventional timber harvest, selective thinning of hardwoods, and use of prescribed fire to maintain early successional stages can be a more cost effective approach. Over a 15-year period on the Pushmataha WMA, the cost/ha of traditional food plots will be $3,180 excluding clearing cost. Over the same period, the cost/ha of timber harvest, thinning, and burning at a 3-year interval would be $1,125. Application of these treatments improves forage standing crop, forage quality, and plant diversity without the costs associated with traditional supplemental forage openings (food plots) (Masters 1991*a*,*b*:148). Deer use of harvested sites was equal to or greater than use of adjacent food plots in all seasons (Masters 1991*b*:244).

Less frequent or no burning allowed woody browse preferred by deer to increase on harvested sites (Landers 1987, Masters 1991*a*). A prescribed burning rotation at 2- to 4-year intervals on harvested sites will increase growth and availability of important deer foods over control or RRB treatments. Winter-prescribed fire at 1- or 2-year intervals favored legumes. Deer forage selectively and have diverse diets (Vangilder et al. 1982, Jenks et al. 1990:8, Masters 1991*a*). The HT4, HT3, HT, and CCSP treatments maximized production and richness of plant groups important to deer (Masters 1991*a*). Benefits from CCSP and HT treatments began to decline in the sixth growing season following timber harvest as the canopy closed. Stem density and percent cover of woody species, particularly post oak and flameleaf sumac, have increased with time on HT3 and HT4 treatments. As flameleaf sumac increases in prevalence, fuel loads will decline because of the phytotoxic effects on growth and germination of other plants (Petranka and McPherson 1979, Smith 1990). When herbaceous plants decrease, fuel loads will decline and periodic burns will be less successful in killing small-diameter hardwoods. This indicates that 3- or 4-year burn intervals will be inadequate to halt secondary succession or maintain higher levels of forage production.

One management option is to increase winter burn frequency after hardwood or pine stem density and canopy cover begin to cause decreases in forage production (Kucera and Koelling 1964). Summer burns might maintain the openness of these sites because growing-season burns are more successful in controlling small-diameter hardwoods (Ferguson 1961, Brender and Copper 1968, Grano 1970). The long-term effects of prescribed fire on vegetation response and site quality in mountainous terrain also should be evaluated. We recommend retaining mature oak-pine stands for acorn production and habitat for other species within a mosaic of HT4, HT3, HT, and CCSP treated sites. The 28% of well-distributed early successional forest openings on the Pushmataha WMA seems adequate to maintain current deer and elk populations without habitat degradation. The proportions and spatial arrangements of these treatments must be developed to make best use of these findings.

Clearcuts should be regenerated as mixed oak-pine stands rather than pure pine stands to retain hardwoods for mast production. Site treatments should be scheduled in different years to provide optimal forage for deer seasonally and between years. Because this study was replicated in small plots on 1 portion of the Pushmataha WMA, inferences are necessarily limited to similar sites on this WMA. Application of these practices in other areas of the Ouachita Mountains, and on a landscape scale, may provide different results. However, production responses of like treatments are similar to those reported by Fenwood et al. (1984) in other areas of the Ouachita Mountains.

SUMMARY

We compared vegetation response following an array of timber harvest and fire regimes on oak-pine sites in the Ouachita Highlands of eastern Oklahoma during 8 years. Nine treatments were replicated 1–3 times in a completely randomized design on 23 (1.2–1.6 ha) units. The treatments were: no treatment control; winter rough reduction burn; clearcut, site preparation, and summer burn; harvest pine only and annual burn; and 5 harvest pine and thin hardwood treatments (to 9 m^2/ha basal area) with no burn, 4-, 3-, 2-, and 1-year winter-burn intervals. Little and big bluestem dominated harvested and winter-burned treatments. Standing crop of these 2 species increased on harvested sites that were burned more frequently. September total standing crop was up to 25 times greater on harvested and burned than on control treatments (4,234 vs. 156 kg/ha). Response was related to overstory canopy cover, basal area, litter accumulation, and burn interval. One- or 2-year winter-burn intervals increased grass and legume production and decreased woody browse species richness. Harvested sites that were unburned or burned at 3- or 4-year intervals allowed woody browse species used by white-tailed deer and possibly elk to increase. Clearcut and summer burned sites were initially dominated by forbs and panicums. As forbs declined, little bluestem increased in frequency and percent ground cover. Forage production declined 6 years postharvest on clearcuts and harvested and unburned sites because of increased canopy cover from pine regeneration. Rough reduction burns increased forage standing crop by only 1.4 times (405 vs. 171 kg/ha). We recommend retaining mature oak-pine stands for acorn production within a mosaic of harvested sites burned every 3–4 years, naturally regenerated, and clearcuts regenerated to mixed oak-pine stands. Site treatments should be applied in different years to provide optimal forage for deer seasonally and between years.

Acknowledgments.—This project was funded in part by Oklahoma Federal Aid to Wildlife Restoration Project W-80-R, Study 4, Job 2, and was a cooperative effort with the Oklahoma Agricultural Experiment Station. This is Journal Article J-6140 of the Oklahoma Agricultural Experiment Station. Appreciation is extended to R. Robinson, F. James, J. Whitehead, and M. Thompson for field assistance, J. Kulbeth for weighing samples, and W. Warde and M. Payton for assistance with statistical design and analysis.

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Received 6 December 1991.
Accepted 4 December 1992.
Associate Editor: Stauffer.

***Wildl. Soc. Bull.* 21:411–414, 1993**

DETECTING CHANGE USING REPEATED MEASURES ANALYSIS: WHITE-TAILED DEER ABUNDANCE AT GETTYSBURG NATIONAL MILITARY PARK

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Management objectives concerning wildlife populations are usually clear—abundance is to be increased, decreased, or unchanged, and change in abundance must be detected. Ideally, annual censuses would detect changes, but for many management situations a census is not feasible. Mark-recapture or mark-resight estimators provide abundance estimates, if all assumptions of the method have been met (Cormack 1972). More often, however, managers must rely on abundance indices, such as the number of animals observed per unit effort. Regardless of attempts to standardize the technique used to assess abundance, the estimates or indices usually are variable. Furthermore, wildlife are not limited by political or administrative boundaries, yet most management units are land-based rather than population-based.

The challenge faced by wildlife managers is to detect a real change in the estimate or index. The statistical techniques that have been used for detecting change have been primarily linear and time series regression (e.g., Sauer and Boyce 1979). Independent observations are a requisite for linear regression. Counts of wildlife that are repeated over time on the same area are not independent observations. Time series regression addresses the question of autocorrelated error terms and is useful for