HABITAT CHARACTERISTICS OF FOREST CLEARINGS CREATED BY PICLORAM HERBICIDES AND CLEAR-CUTTING[1]

WILLIAM C. MCCOMB, Department of Forestry, University of Kentucky, Lexington, KY 40546
ROBERT L. RUMSEY,[2] Department of Forestry, University of Kentucky, Lexington, KY 40546

Abstract: Twenty-six habitat characteristics were quantified on untreated, clearcut, and picloram-treated plots on north-facing, south-facing, and ridgetop sites in eastern Kentucky. Twenty-one habitat characteristics differed among treatments and 13 characteristics differed among aspects. Herbicide plots were intermediate between untreated and clearcut plots in 15 characteristics. Hard and some soft mast species and browse species were adversely affected by increasing concentrations of herbicide, but snag and log abundance were increased by herbicide application. Hard mast species composition, foliage height diversity, and leaf cover were highest on untreated areas. Soft mast and browse species composition, and log, stump, and rock abundance were best on south-facing clearcuts. Snag abundance and diameter were greatest on ridgetop and south-facing plots receiveing 68 kg/ha of TORDON 10K. An application rate of 23 kg/ha of TORDON 10K on south-facing slopes provided 23 habitat characteristics which were equal to or better than untreated plots.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 35:174-184

Increasing interspersion and/or intraspersion of forest habitat by cutting are accepted methods of increasing the diversity and abundance of wildlife species which benefit from 2 or more habitat types, or 2 or more vegetative strata (Thomas 1979). Sweeney (1980) suggested some guidelines for forest managment practices to diversify the structure and composition of wildlife habitat in mid-South hardwoods by cutting. More specifically, the effects on wildlife of interspersion by clearcutting have been investigated by Harlow and Downing (1969), Titterington et al. (1979), Hahn and Michael (1980), and others. The effects on wildlife habitat of liquid herbicide application for wildlife and/or forestry benefits have been examined by Krefting and Hansen (1969) and Kirkland (1978). Pelleted herbicides are currently being used in forest management (Peevy 1973, Loftis 1978, Dewey 1980), and McCaffery et al. (1974) suggested using pelleted herbicides to maintain wildlife openings in Wisconsin. Openings created by herbicides are more economical than felling or girdling trees, especially in remote or rugged terrain. Picloram-based herbicides are desirable for creating forest clearings because of low toxicity to many vertebrate species (Kenaga 1969). Our objectives were to compare the

[1] The investigation reported in this manuscript (No. 81-8-48) is in connnection with Kentucky Agricultural Experiment Station Project No. 620 and is published with the approval of the Director.

[2] Present address: Department of Agriculture, McNeese State University, Lake Charles, LA 70609.

structure and composition of wildlife habitats among untreated, clearcut, and herbicide-created openings, on north-facing, south-facing, and ridgetop sites.

We wish to thank M. J. Immel for advice on statistical analyses; J. B. Davis, G. M. Gigante, and the Robinson Forest staff for assistance in field work; Dow Chemical Co. for providing herbicides; and B. A. Thielges, R. E. Noble, R.N. Muller and S. B. Carpenter for reviewing an early draft of this manuscript.

METHODS AND STUDY AREA

Snag Ridge Fork watershed, in the University of Kentucky's Robinson Forest, Knott County, Kentucky is a mixed mesophytic forest typical of much of the central Appalachians (Carpenter and Rumsey 1976). Ridges are dominated by shortleaf pine *(Pinus echinata)*, pitch pine *(P. rigida)*, chestnut oak *(Quercus prinus)*, and scarlet oak *(Q. coccinea)*; south-facing slopes by hickories (*Carya* spp.), white oak *(Q. alba)*, black oak *(Q. velutina)*, and sourwood *(Oxydendrum arboreum)*; and north-facing slopes by northern red oak *(Q. rubra)*, cucumbertree *(Magnolia acuminata)*, and yellow-poplar *(Liriodendron tulipifera)*. The forest has a history of high-grading and fire abuse (Carpenter 1976). Dominant trees were 50 - 60 years old and averaged 30 - 45 cm dbh. Thirty-six 0.4-ha square plots were established on the watershed. Ten plots on each of a north-facing slope, south-facing slope, and ridge-top randomly received 1 of the following hand-broadcast herbicide treatments in May 1976 (Mention of trade names is for identification and does not imply endorsement by the Kentucky Agricultural Experiment Station, Lexington, KY): 3 plots, 23 kg/ha TORDON 10K (T23); 3 plots, 45 kg/ha TORDON 10K (T45); 3 plots, 68 kg/ha TORDON 10K (T68); and 1 plot, 90 kg/ha M-3864 (M90). TORDON 10K is a pelletized picloram-based (4-amino-3, 5, 6-trichloropicolonic acid) herbicide, and M-3864 is a 5% picloram pellet. One plot on each aspect was clearcut; felled trees were not removed. One plot on each aspect was established in untreated forest at least 75 m from any treated plot. Treated plots were 15 to 50 m apart. Fifty trees were chosen at random through the center of each plot, perpendicular to the contour, for evaluation of crown kill in August 1976.

Sweeney (1980) divided wildlife habitat in mid-South hardwoods into 4 components: mast, forage, snags, and vertical diversity. Within the constraints of our study area we recognized ground cover (logs, rocks, leaves, etc.) and physiographic features (slope and water availability) as additional components potentially important to wildlife. Twenty-one microsite characteristics, chosen on the basis of previous studies (Dueser and Shugart 1978, Geier and Best 1980) were measured at 15 stations through the center of 18 plots; each treatment on each aspect (Table 1). Estimates of cover by rocks, logs, leaves, canopy, and midstory followed methods described by James and Shugart (1971). Distances to trees, snags, rocks, stumps, and logs were used as indices to density based on Pielou's (1977) nearest neighbor concept. Understory vegetation was quantified on 4-m^2 circular plots 2 m along the contour from each station in January 1980. A modified Aldous method was used similar to that described by Murphy and Noble (1972). Percent cover and stem density were determined for each plant taxon on each 4-m^2 plot. Relative density, relative dominance, and relative frequency were summed to develop an importance value for each taxon on each plot. Total cover, total density, plant species richness, and Shannon-Weaver plant species diversity were calculated for each station. Foliage height diversity was calculated at each station based on understory, midstory, and overstory cover. Analysis of variance and Duncan's New Multiple Range Test were used to compare habitat characteristics among treatments and aspects (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Twenty-one of the 26 habitat characteristics differed ($P < 0.05$) among treatments (Table 2). Herbicide plots were characterized by relatively many snags, low midstory cover, and high understory cover and density. Clearcuts were characterized by no overstory except at the edge, dense understory, many stumps, logs, and rocks, low leaf cover, high understory density and high understory diversity. Control plots were characterized by dense crown cover, high basal area, low understory cover, few snags, few logs, and few rocks.

Table 1. Habitat variables quantified on uncut, clearcut, and herbicide plots, Knott County, Kentucky, May 1980.

Acronym	Description
NTR	Number of trees > 10 cm dbh within 2 m of a station.
DMT	Diameter (dbh) of the nearest tree (cm).
DST	Distance to the nearest tree (m).
BA	Basal area of living stem (m^2/ha).
NSN	Number of snags > 10 cm dbh, > 1.8 m tall within 2 m of a station.
DMS	Diameter of the nearest snag (cm).
DSS	Distance to the nearest snag (m).
NSP	Number of stumps > 10 cm dbh within 2 m of a station.
DSP	Distance to the nearest stump (m).
NLG	Number of logs > 10 cm diameter, > 1.8 m long,within 2 m of a station.
DML	Maximum diameter of the nearest log (cm).
LGL	Length of the nearest log (m).
DSL	Distance to the nearest log (m).
PCL	Percent of ground covered by logs within 2 m of a station.
DSR	Distance to the nearest rock > 5 cm above ground.
PCR	Percent of ground covered by rocks.
CRN	Percent crown cover above 6.1 m at a station.
MID	Percent vegetation cover between 1.8 and 6.1 m at a station.
LFC	Percent of the ground covered by fallen leaves.
CV1	Percent understory cover < 1.8 m tall in Jan.
DN1	Number of understory stems per 4-m^2 plot in Jan.
R1	Number of understory taxa per 4-m^2 plot in Jan.
DV1	Understory species diversity per 4-m^2 plot in Jan.
H'	Foliage height diversity; Shannon-Weaver formula, n_i = % cover of the ith stratum.
DWT	Distance to water (m).
SLP	Slope (%).

Table 2. Mean habitat characteristics which differed among treatments, Robinson Forest, Knott County, Kentucky, May 1980.

Habitat	Control	Clearcut	Herbicide (Kg/ha)			
Characteristic[a]			23	45	68	90
NTR	0.6A[b]	0.1C	0.4AB	0.3BC	0.3BC	0.3BC
DST	2.8C	18.3A	3.0C	3.4BC	5.3B	4.3BC
BA	24.6A	9.3D	17.5C	20.4B	17.2C	21.1B
NSN	.0C	.0C	0.1C	0.2B	0.4A	0.4A
DMS	20.5C	22.2BC	34.6A	21.9BC	34.8A	27.2BC
DSS	11.8B	29.2A	7.4C	4.3D	3.7D	4.7D
NSP	0.3B	0.8A	0.1B	0.2B	0.3B	0.2B
DSP	5.7AB	2.5C	7.0A	7.0A	4.5B	5.1B
NLG	0.3D	3.5A	1.2C	1.2C	2.0B	1.0CD
DML	19.8C	36.5A	31.2B	22.7BC	25.5BC	28.1BC
LGL	6.3B	14.2A	7.2B	8.0B	8.1B	8.0B
DSL	6.9A	1.2C	3.3B	2.4BC	2.5BC	3.3B
PCL	1.1C	22.3A	5.8B	5.6B	6.7B	4.6BC
DSR	19.5A	4.0E	10.0BC	8.4CD	12.4B	5.8DE
PCR	1.2C	6.7A	4.1B	2.1BC	3.3BC	2.3BC
CRN	67.4A	3.9C	37.7B	35.7B	13.0C	31.9B
MID	46.0A	40.9AB	30.4BC	20.4CD	17.1D	13.0D
LFC	86.1A	26.8D	63.4B	61.4B	43.7C	54.8B
H'	1.33A	1.16C	1.24B	1.20B C	1.24B	1.24B
DWT	57.7C	162.7A	112.7B	89.0B	94.0B	98.4B
SLP	29.4C	30.2C	50.3A	35.6BC	41.2B	30.3C

[a] Defined in Table 1.
[b] Means with different letters vary significantly ($P < 0.05$).

Thirteen of the habitat characteristics varied significantly among aspects ($P < 0.05$). Ridges were characterized by relatively large diameter trees, high crown cover, gradual slope, and few rocks. South-facing slopes were characterized by relatively high basal area, many rocks, and little leaf cover. North-facing slopes were characterized by relatively low understory density, low understory diversity, and high foliage height diversity.

Hard Mast

Herbicides and clearcutting decreased the density and species richness of mast-bearing tree species. Eight of the 11 tree species found on control plots were hard mast producers, with red oaks (Erythrobalanus), white oaks (Leucobalanus), and hickories represented. Control plots had higher basal area ($\overline{X} = 24.6$ m^2/ha; SD = 5.9), higher crown cover ($\overline{X} = 67.4\%$; SD = 18.4), and higher tree density ($\overline{X} = 2.8$ m between trees; SD = 4.7) ($P < 0.05$) than treated plots. Trees at the edges of clearcuts may have increased mast production following crown enlargement from increased light availability (Goodrum et al. 1971).

Pines (*Pinus* spp.), sassafras *(Sassafras albidum)*, yellow-poplar, and flowering dogwood *(Cornus florida)* were most severly affected by herbicides ($\overline{X} = 100$, 93, 95, and 85% crown kill after 2 growing seasons, respectively). Crown kill of hickories, white oak, chestnut oak, northern red oak, black oak, and red maple *(Acer rubrum)* increased with increasing concentration of herbicide ($P < 0.05$). Relative density of scarlet oak and blackgum *(Nyssa sylvatica)* increased with increasing herbicide concentration. Herbicide affected not only the species composition of the plots, but also the basal area. T23 and T68 had similar stocking ($\bar{X}$ = 17.4 m^2/ha; SD = 4.5), but T23 had more mast species (7) than T68 (5). T45 and M90 had higher ($P < 0.05$) basal area ($\bar{X}$ = 20.8 m^2/ha; SD = 5.2) than T23 and T68, and T45 and M90 had a similar number of mast species (7 and 6, respectively). M90 had a more uniform stocking of red and white oaks than T45 which was predominantly chestnut oak. Basal area reduction by herbicide may increase mast production because increased light penetration of the canopy should increase crown size and hence mast production (Goodrum et al. 1971). If that is the case, then M90 probably would be the best herbicide treatment for hard mast production.

Hard mast production may be affected by aspect. Hickories were most easily killed on north slopes and most difficult to kill on ridgetops. Conversely, northern red oak was easiest to kill on south-facing slopes , most difficult to kill on north-facing slopes. Ridgetops and south-facing slopes had more mast species occurring *more frequently (88% relative frequency) than north-facing slopes* (6 species and 62% frequency). Basal area was higher ($P < 0.05$) on south-facing slopes ($\bar{X}$ = 19.7 m^2/ha; SD = 7.0) than on ridgetops and north-facing slopes ($\bar{X}$ = 18.0 m^2 SD = 6.8), but crown cover was highest on north-facing slopes ($\bar{X}$ = 24.8%; SD = 7.0). Tree density was seemingly unaffected by aspect, but trees on ridgetops were larger ($P < 0.05$) in diameter than trees on north- or south-facing slopes. The combination of low basal area, large boles, large crowns, and abundant mast species would probably make ridgetops more productive of mast than north- or south-facing slopes (Goodrum et al. 1971).

Soft Mast, Browse, and Understory Cover

Understory cover was correlated ($P < 0.05$) with crown cover (-0.24) (correlation coeffieients indicated parenthetically), and basal area (-0.20); understory density with percent slope (+0.23), and basal area (–0.23); understory species richness with percent slope (+0.26) and basal area (–0.18); and understory diversity with basal area (–0.30), crown cover (–0.27), and percent slope (+.23). Ehrenreich and Crosby (1960), Halls (1973), and others reported crown cover and basal area inversely related to understory cover. Understory cover ($\bar{X}$ = 105.6%; SD = 49.5), stem density ($\bar{X}$ = 88.8 stems/4-m^2; SD = 18.9), species richness ($\bar{X}$ = 7.1 species/4-m^2; SD = 2.5), and Shannon-Weaver diversity ($\bar{X}$ = 5.3; SD = 0.6) did not vary significantly among treatments. Understory density and diversity were higher ($P < 0.05$) on ridgetops and south-facing slopes than on north-facing slopes. Differences among aspects are probably a response to differences in overstory suppression and solar insolation (Byram and Jemison 1943).

Eighteen plant taxa had the highest importance values on the 6 treatments (Table 3). Ten of these taxa are each important soft mast producers for 10 to 36 species of indigenous birds and mammals, and fruits or seeds from 5 other taxa are eaten by at least 1 wildlife species (Martin et al. 1951). Fruit production of yellow-poplar, sassafras, blackgum, red maple, and flowering dogwood is dependent upon crown cover (Halls 1973), but these plants represent potential browse in this study and may produce fruit in the future if their relative importance on the plots is maintained. Species richness, was greatest on T23, T45, and M90 ($\bar{X}$ = 55 taxa), and lowest on controls, clearcuts and T68 ($\bar{X}$ = 39 taxa). Herbicide plots were dominated by grasses, greenbriers (*Smilax* spp.), blackberries (*Rubus* spp.), sassafras, and red maple. Effects on plants of picloram application were dependent on concentrations and species. Blueberries (*Vaccinium* spp.) were adversely affected by any herbicide concentration. The importance values of Christmas fern (*Polystichum acrostichoides*), greenbriers, chestnut oak, blackberry, wood vetch, and yellow-poplar increased with increasing concentrations of TORDON 10K. The importance of grasses, New Jersey-tea *(Ceanothus americanus)*, cinquefoil, blackgum, and sassafras decreased with increasing concentrations of TORDON 10K. The importance values of Christmas fern, grasses, greenbriers, and blackgum were highest on M90. M-3864 did not affect grasses and blackgum as severely as TORDON 10K.

The importance values of New Jersey-tea, eastern redbud *(Cercis canadensis)* flowering dogwood, red maple, and maple-leaf viburnum *(Viburnum acerifolium)* were highest on control plots. Shade tolerance of these species probably allowed them to be more important members of the understory community on control plots than on treated plots. Fruit and browse production by these species may be enhanced by release through cutting or herbicide application (Halls and Alcaniz 1968, Krefting and Hansen 1969), but fenuron may be more effective than picloram for release of flowering dogwood (Gill and Healy 1974: 41).

Clearcuts were dominated by greenbriers, blackberry, sassafras, and grapes (*Vitis* spp.). Release of these moderately shade intolerant species allowed them to dominate clearcuts. High density of these species in addition to eastern redbud, flowering dogwood, and red maple made clearcuts almost impenetrable to humans after 4 years. Harlow and Downing (1969) found clearcuts in central Appalachians of limited value to deer for this reason, but understory fruit and browse production were probably highest on clearcuts during the first 4 years after cutting, (Della-Bianca and Johnson 1965).

Browse and fruit-producing species were affected by aspect. Ridges were dominated by grasses, greenbriers, flowering dogwood, sassafras, and red maple; south-facing slopes by Christmas fern, grasses, greenbriers, and blackberries; and north-facing slopes by Christmas fern, greenbriers, flowering dogwood, red maple, and asters (*Aster* spp.). We found blackgum and flowering dogwood more important on north-facing than south-facing slopes; similar to Murphy and Ehrenreich's (1965) findings in Missouri.

Reduction of crown cover by herbicides would best be performed with 23 kg/ha of TORDON 10K on ridgetops or south-facing slopes for maximum density and diversity of soft-mast and browse species.

Snags

We found more snags on herbicide-treated plots than clearcut and uncut plots ($P < 0.05$) (Table 2). Snag density was maximized by herbicide concentrations between 45 and 90 kg/ha. Snag density did not differ among aspects ($P < 0.05$). Snag diameters were largest on T23 and T68 ($P < 0.05$) ($\bar{X}$= 34.7 cm; SD = 19.7) and on south-facing slopes ($P < 0.05$) ($\bar{X}$ = 36.2 cm; SD = 17.8). We did not determine the effects that herbicides had on fungal formations, decomposition

Table 3. Importance values of selected understory taxa among clearcut, herbicide-treated, and untreated plots, Knott County, Kentucky, Jan 1980.[a]

	Control	Clearcut	Herbicide (kg/ha)				Total
Taxon	(N=45)	(N=45)	23(N=45)	45(N=45)	68(N=45)	90(N=45)	(N=270)
Smilax rotundifolia and *S. glauca*	55.7	50.1	24.6	34.4	50.5	62.2	277.5
Rubus allegheniensis	5.6	32.2	13.2	29.3	32.4	28.9	141.6
Cornus florida	62.8	22.3	15.7	22.9	4.0	11.3	139.0
Acer rubrum	35.1	18.5	13.8	22.7	16.1	7.1	113.3
Aster spp.	1.3	11.7	28.4	16.2	33.6	17.1	108.3
Sassafras albidum	5.7	34.9	22.4	12.1	10.9	17.1	103.1
Poaceae	14.9	1.4	27.9	11.1	6.5	40.0	101.8
Polystichum acrostichoides	4.4	4.1	9.8	11.7	27.9	20.7	78.6
Liriodendron tulipifera	1.3	5.5	8.6	17.5	19.7	8.6	61.2
Nyssa sylvatica	8.1	3.4	9.4	9.1	8.5	13.7	52.2
Quercus prinus	10.3	7.1	2.9	8.1	12.3	4.8	45.5
Vitis spp.	0.7	30.7	4.3	2.7	0.0	1.1	39.5
Vaccinium spp.	14.4	14.1	2.9	0.7	1.2	3.1	36.4
Cercis canadensis	6.2	7.1	0.8	5.0	0.6	3.7	23.4
Vicia virginiana	4.6	0.0	0.0	6.1	9.2	0.0	19.9
Ceanothus americanus	8.3	1.1	5.7	0.5	0.0	3.0	18.6
Potentilla canadensis	0.0	0.0	14.0	4.2	0.0	0.0	18.2
Vibrunum acerifolium	8.4	0.0	0.7	0.0	3.4	0.7	16.2
Other taxa	52.7	55.8	91.9	85.7	63.2	56.9	405.8
Number of other taxa	16	23	36	38	24	36	54

[a] Taxa selected ranked in the top 10 on at least 1 treatment.

rates, and insect populations. Wildlife use of herbicide-created snags may differ from use of natural snags.

Verical Diversity

MacArthur and MacArthur (1961) found that foliage height density (FHD) based on 3 layers was strongly correlated with bird species diversity (BSD), and that plant species diversity (PSD) may also be a good indicator of BSD.

Foliage height diversity was highest on control plots and lowest on the clearcuts ($P < 0.05$). Herbicide plots were intermediate in FHD. Overstory tree species diversity decreased from control plots to herbicide-treated plots to clearcuts. Understory species diversity increased from control plots to herbicide-treated plots to clearcuts. Consequently, the diversity and species composition of birds in each strata will likely change. Crown-dwelling species probably would be most abundant on uncut and lightly herbicide-treated plots, and absent from clearcuts. Understory dwellers probably would be mot abundant on clearcut or herbicide-treated plots. Midstory dwellers probably would be most abundant on clearcut and control plots ($\bar{X}$ = 43.5% cover; SD = 33.8) and least abundant on T68 and M90 ($\bar{X}$ = 15.1% cover; SD = 23.7). Willson (1974) found highest BSD on areas with trees and shrubs, and with a total cover between 140 and 160%. This condition was most closely approached on T45.

FHD was affected by aspect, being highest on north slopes, lowest on south slopes, and intermediate on ridges ($P < 0.05$). Crown cover was the only stratum to vary significantly among aspects ($P < 0.05$). Shugart and James (1973) and Smith (1977) found bird species richness lower on xeric sites than on mesic sites. BSD probably would be lower on south-facing slopes than north-facing slopes.

Ground Cover

Logs and rocks are used as cover by small mammals and herpetofauna. Clearcuts provided logs with the most desirable characteristics: highest density, largest diameter, and greatest length ($P < 0.05$) (Table 2). These log characteristics may not be present where clearcuts are for commercial exploitation rather than for development of wildlife clearings. Of the herbicide plots, T68 had the highest log density ($P < 0.05$), but diameters, lengths, and percent ground cover did not differ ($P < 0.05$) among herbicide-treated plots. Control areas supported the fewest and smallest logs ($P < 0.05$). Log characteristics did not differ among aspects ($P < 0.05$).

Clearcuts had the greatest amount of ground covered by exposed rocks of any treatment ($P < 0.05$), and control plots had the lowest rock cover. On the herbicide plots, rocks were most dense on M90. Rocks were more dense on south-facing slopes than on north-facing slopes, and more dense on north-facing slopes than on ridgetops ($P < 0.05$). Rock cover was lower ($P < 0.05$) on ridgetops than on either north- or south-facing slopes. Leaf cover probably affected rock cover. Underlying rocks were exposed as leaf litter decomposed. Gottschalk and Shure (1979) found that 2, 4, 5-T application increased decomposition rates within the litter layer. Bormann and Likens (1979:52) indicated that clearcutting increased decomposition of dead plant material. We found highest leaf cover on control plots and lowest leaf cover on herbicide and clearcut plots ($P < 0.05$) and leaf cover was lower on south-facing slopes than on ridges or north-facing slopes.

Thomas (1979) indicated that stumps, along with other woody debris, enhance the habitat diversity of forest floor. We found stumps most abundant on clearcuts, least abundant on T23 and T45, and intermediate on T68, M90, and control plots ($P < 0.05$). The mean distance to a stump was shorter on north-facing slopes than on ridgetops or on south-facing slopes ($P < 0.05$).

MANAGEMENT IMPLICATIONS

Uncut forests provided the best mast species composition and structure. Selective treatment of pines, yellow-poplar, red maple, and sassafras on south-facing slopes to release oaks and hickories may increase mast production as well as foliage height diversity. Treatment of blocks of forest with herbicide were not beneficial to hard mast species, because crown-kill increased in 5 mast-bearing taxa with increasing herbicide concentration. Vertical diversity and leaf cover were highest on uncut plots. Herbicides or cutting allowed an increase in decomposition rates and a decrease in leaf cover, which is important to some fossorial insectivores (Getz 1961), and these treatments decreased FHD but increased edge.

Twenty-three kg/ha of TORDON 10K on south-facing slopes was the best conpromise treatment for maintaining hard mast species and FHD, releasing understory, and increasing snag density and log density. Optimum values were attained for 4 of the habitat characteristics with this concentration, and intermediate values were attained for 14 of 26 habitat characteristics.

Forty-five kg/ha of TORDON 10K on north slopes provided desirable FHD for songbirds and intermediate habitat for species requiring dense understory vegetation, soft mast, snags, logs, and/or rocks. Stumps were lacking after 4 years.

Sixty-eight kg/ha of TORDON 10K on south-facing slopes maintained understory density and diversity, encouraged some soft mast and browse plants, maximized density and diameter of snags, and provided abundant logs. Some soft mast and browse species (blueberries, New Jersey-tea, sassafras, grapes, and cinquefoil) and most hard mast species would be discouraged by T68. McCaffery et al. (1974) suggested that picloram should not be broadcast to maintain wildlife openings because some important food plants were adversely affected.

Ninety kg/ha of M-3864 on south-facing slopes or ridgetops provided abundant rocks and relatively good mast species composition; it also provided intermediate log, stump, snag, and FHD characteristics. This treatment is a more expensive compromise than T27, but provides many of the same habitat characteristics.

Clearcuts provided excellent soft mast and browse species composition, and abundant stumps, logs, and rocks. White-tailed deer may not benefit from the increased available food supply on clearcuts but they may use clearcuts for cover. Clearcuts provided no snags, little vertical diversity, and no hard mast species.

Clearcuts and herbicide-treated plots are dynamic; plant species composition and habitat structure will change with time. Thus, the long-term effects of pelleted herbicide application should be investigated further. McCaffery et al. (1974) found that woody vegetation reestablished more slowly 2 years after herbicide application than they did after mechanical control. At the rates we used, herbicide should be reduced to 0.1g/ha in 2 to 3 years (Hamaker et al. 1967). Residual herbicide may reduce reestablishment of some plant species and delay the time between treatments, thereby further reducing the cost per ha per year of establishing forest clearings.

LITERATURE CITED

Bormann, F. H., and G. E. Likens. 1979. Pattern and process in a forested ecosystem. Springer-verlag, New York. 253pp.

Byram, G. M., and G. M. Jemison. 1943. Solar radiation and forest fuel moisture. J. Agric. Res. 67:149-176.

Carpenter, S. B. 1976. Stand structure of a forest in the Cumberland Plateau of eastern Kentucky fifty years after logging and burning. Castanea 41:325-337.

__________, and R. L. Rumsey, 1976. Trees and shrubs of Robinson Forest, Breathitt County, Kentucky. Castanea 41:277-282.

Della-Bianca, L., and R. M. Johnson. 1965. Effect of an intensive clearing on deer-browse production in the southern Appalachians. J. Wildl. Manage. 29:729-733.

Dueser, R. D., and H. H. Shugart, Jr. 1978. Microhabitats in a forest-floor small mammal fauna. Ecology 59:89-98.

Dewey, J. B. 1980. "Gridball Pellets" — a new tool for brush control in pines. For. Farmer 39(20):14-15, 34.

Ehrenreich, J. H., and J. S. Crosby. 1960. Herbage production is related to hardwood crown cover. J. For. 58:564-565.

Geier, A. R., and L. B. Best. 1980. Habitat selection by small mammals of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44:16-24.

Getz, L. L. 1961. Factors influencing the local distribution of shrews. Am. Midl. Nat. 65:67-88.

Gill, J. D., and W. M. Healy. 1974. Shrubs and vines for northeastern wildlife. U. S. Dep. Agric. Gen. Tech. Rep. NE-9. 180pp.

Goodrum, P. D., V. H. Reid, and C. F. Boyd. 1971. Acorn yields, characteristics and management criteria of oaks for wildlife. J. Wildl. Manage. 35:520-532.

Gottschalk, M. R., and D. J. Shure. 1979. Herbicide effects on leaf litter decomposition processes in an oak-hickory forest. Ecology 60:143-151.

Hahn, B. L., and E. D. Michael. 1980. Response of small mammals to whole tree harvesting in central Appalachia. Trans. Northeast Fish and Wildl. Conf. 37:32-44.

Halls, L. K. 1973. Flowering and fruiting of southern browse species. U.S. Dep. Agric. For. Serv. Res. Pap. SO-90. 10pp.

__________, and R. Alcaniz. 1968. Browse plants yield best in forest openings. J. Wildl. Manage. 32:185-186.

Hamaker, J. R., C. R. Youngson, and C. A. I. Goring. 1967. Prediction of the persistence and activity of TORDON herbicide in soils under field conditions. Down-to-Earth 23(2):30-36.

Harlow, R. F., and R. L. Downing. 1969. The effects of size and intensity of cut on production and utilization of some deer foods in the southern Appalachians. Trans. Northeast Fish and Wildl. Conf. 26:45-55.

James, F. C., and H. H. Shugart, Jr. 1971. A quantitative method of habitat description. Aud. Field Notes 24:727-736.

Kenaga, E. E. 1969. Tordon herbicide-evaluation of safety to fish and birds. Down-to-Earth 25(1):5-9.

Kirkland, G. L., Jr. 1978. Population and community responses of small mammals to 2,4,5-T. USDA for. Serv. Res. Note PNW-314., 7pp.
Krefting, L. W., and H. L. Hansen. 1969. Increasing browse for deer by aerial applications of 2,4-D. J. Wildl. Manage. 33:784-790.
Loftis, D. L. 1978. Preharvest herbicide control of undesirable vegetation in southern Appalachian hardwoods. South. J. Appl. For. 2:51-54.
MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594-598.
Martin, A. C., H. S. Zim, and A. L. Nelson. 1951. American wildlife and plants a guide to wildlife food habits. McGraw-Hill Book Co., Inc., New York. 500pp.
McCaffery, K. R., F. L. Johnson, and L. D. Martoglio. 1974. Maintaining wildlife openings with pellets containing picloram. Wildl. Soc. Bull., 2:40-45.
Murphy, D. A., and J. H. Ehrenreich. 1965. Effects of timber harvest and stand improvement on forage production. J. Wildl. Manage. 29:734-739.
Murphy, P. K., and R. E. Noble. 1972. The monthly availability and use of browse plants by deer on a bottomland hardwood area in Tensas Parish, Louisiana. Proc. Ann. Conf. S.E. Assoc. Game and Fish Comm. 26:39-57.
Peevy, F. A. 1973. Bromacil and picloram under southern upland hardwoods. J. Weed Sci. Soc. Am. 21:54-56.
Pielou, E. C. .1977. Mathematical ecology. John Wiley and Sons, Inc., New York. 385pp.
Shugart, H. H., Jr., and D. James. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. Auk 90:62-77.
Smith, K. G. 1977. Distribution of summer birds along a forest moisture gradient in an Ozark watershed. Ecology 58:810-819.
Steel, R. G., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., New York 481pp.
Sweeney, J. M. 1980. Wildlife habitat management in mid-South upland hardwoods. Pages 144-151 *in* F. Shropshire and D. Sims, eds. Proc. mid-South upland hardwood sympos. for the practicing forester and land manager. USDA For. Serv. Tech. Publ. SA-TP 12.
Titterington, R. W., H. S. Crawford, and B. N. Burgason. 1979. Songbird responses to commercial clearcutting in Maine spruce-fir forests. J. Wildl. Manage. 43:602-609.
Thomas, J. W. 1979. Wildlife habitats in managed forests the Blue Mountains of Oregon and Washington. USDA For. Serv. Agric. Handb. No. 553. 512pp.
Willson, M. F. 1974. Avian community organization and structure. Ecology 55:1017-1029.