Development of Wildlife Food and Cover on an Electric Transmission Right-of-Way Maintained by Herbicides: A 30-Year Report

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Development of Wildlife Food and Cover on an Electric Transmission Right-of-Way Maintained by Herbicides: A 30-Year Report

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Summary

A 30-year study of effects of herbicide sprays on wildlife food and cover has been carried out in central Pennsylvania on a 180-foot-wide electric transmission right-of-way to answer the question, "Do herbicides damage wildlife habitat?" The herbicides used were 2,4-D, 2,4,5-T and ammonium sulfamate. Highly acceptable control of tall-growing woody species was maintained, and excellent wildlife habitat conditions were developed by five different initial spray applications followed by selective herbicide spray maintenance. Following initial differences in plant cover produced by broadcast and selective basal applications, a dominant shrub cover interspersed with herbaceous openings developed on all treatment areas.

Abundant fruiting of shrubs such as blueberry, huckleberry, blackberry, dewberry, witch-hazel, and bear oak on the right-of-way produced valuable wildlife food. Browsing on the leaves and stems of those species, plus sweetfern, grasses and herbs, such as bracken, goldenrod, loosestrife, and sheep sorrel, provided additional food. Shrubby right-of-way edges formed by witch-hazel and bear oak produced both food and cover. The common plant food species available on the right-of-way rated high in wildlife feed value. Frequent use of the right-of-way by common game and nongame wildlife was documented during the 30 years.

Vegetation development progressed from a dominance by forest species to a codominance between forest plants and species of openings. A typical proclimax vegetation type resulted that may be maintained by tree removal with herbicides. This proclimax is characterized by high species density and richness, and a consistent floristic composition. Plant species that became dominants were all capable of underground vegetative spread by rhizomes or rhizomatous roots and formed patch-like mosaics on the right-of-way. Information obtained from the study can be used to attain desired objectives on rights-of-way through management planning.

Introduction

A long-term study has been carried out over a period of 30 years on a right-of-way (ROW) traversing an oak-hickory forest in central Pennsylvania. The study was designed to investigate (1) the effects of herbicide applications on game food and cover, (2) use of the ROW by wildlife species, (3) development of a low, dense plant cover, and (4) long- and short-term changes in vegetation to determine the nature and stability of the plant communities which developed over time.

In this study of development of vegetation on ROWs, it was important to differentiate between short-term fluctuations and long-term progressive development (Knapp, 1974). Fluctuations on ROWs are those changes that occur annually, or within short periods, after which the vegetation tends to return rapidly to approximately the original condition. These are generally caused by fluctuations in climatic site factors such as wet or dry years and frost damage, and by biotic factors such as deer browsing, which may vary with deer populations. There also may be other minor fluctuations in plant species owing to natural maturing and senescence of species, and to variations in annual seed production.

Long-term progressive development on the ROW studied refers to those changes which have moved towards a proclimax type of vegetation (Grime, 1979). As the ROW used in this study intersects a forested area, the normal progressive development (succession) would be a long-term trend from a herb-grass, or an open shrub-herb-grass community, towards a forest community. However, continuous maintenance of the ROW by herbicide sprays removed forest trees that became established on the ROW. Tree removal prevented natural development to a climax forest condition and, consequently, led to a sustained proclimax vegetation.

The complex species composition of ROW vegetation is a result of a number of interacting factors which can be expressed by a simple equation (Mueller-Dombois and Ellenberg, 1974). In this equation the factors acting in the formation of a ROW plant community are expressed as **Plant community = F (f, a, e, h, d, t)**, where "F" is a function and:

- f = flora of the area which may include seeds and plant parts in place on the ROW, or that may move in by invasion.
- a = accessibility, or ability of a species to reach an area (invasion and establishment).
- e = ecological characteristics of plants which influence their ability to compete (life form, reproductive processes, habitat requirements, etc.).
- h = habitat, which is the sum of the total environmental factors.
- d = disturbance caused by ROW clearance and maintenance.
- t = time that has passed since a major event (such as mechanical clearance or herbicide spraying) has occurred that initiated the vegetation change.

Changes in the complex set of conditions described above generally leads to appreciable variations within any certain plant community and emphasizes the need for the simplified approach which is described under "Methods" in the following section. These wide variations make use of random sampling and statistical approaches difficult and unduly time-consuming as has been pointed out by Braun-Blanquet (1964). A floristic approach with broad class estimates of species cover has been used, therefore, to best meet the aims of this ROW study.

An understanding of the changes which occur in nontarget vegetation on electric transmission ROWs has become an important aspect of management planning. An ecological approach to ROW management was thoroughly discussed by Egler (1975). Olenik and Rossman (1977) have indicated that ROW management now calls for a professional approach that involves not only control of unwanted tree species but also the manipulation of desirable nontarget vegetation to enhance such values as wildlife food and cover and visual appearance. Johns (1976) stated that ROW managers and others responsible for policy need to evaluate the short- and long-term effects of management techniques on vegetation and aesthetics. In New York state, for example, ROW managers have been specifically charged with control of tall-growing species capable of interfering with electric transmission and with development of a desirable plant cover of nontarget species (NY PSC, 1980).

Several major research studies reported in recent years have described some general features of vegetation development on ROWs maintained by herbicides. Niering and Goodwin (1974) described development of stable shrublands and less stable herblands on a ROW in Connecticut, composed of post-agricultural vegetation, maintained by selective use of herbicides. Carvell and Johnston (1978) in a study of national scope reported that repeated broadcast herbicide sprays produced a low plant cover dominated by sedges, grasses, ferns, or herbicide-resistant woody species, while selective herbicide treatments have caused a gradual increase in shrubs. A study made in New York (Asplundh Environmental Services, 1977) documented the effects of past ROW management on vegetation on 22 ROWs as a basis for management decisions involving effects of herbicides on nontarget vegetation. Johnston and Bramble (1979) analyzed the vegetation that has developed on 18 ROWs in New York state in relation to habitat and forest region and have described characteristic communities typical of three major habitats.

Broadcast-sprayed plots in Minnesota were dominated by more grasses and forbs than the selective basal-sprayed plots (Perala and Sorensen, 1979). A mixed shrub community dominated the selective basal-sprayed plots, while broadcast plots were

dominated by raspberry. Huntley and Arner (1979) propose that a combination of ROW maintenance techniques be used to develop wildlife food and cover and that selective basal spraying be used to establish shrubby habitats adjacent to grass-herb burned areas on southern ROWs.

Background

In the spring of 1953, an investigation of the effects of commonly-used herbicide spray techniques for vegetation management was initiated on a 3.0 mile section of a new power line ROW in central Pennsylvania (Bramble and Byrnes, 1955). The ROW had been cleared in the winter of 1951-52 through a mixed oak forest type typical of the Appalachian forest area. The test was arranged in a randomized complete block design with each of the original treatments replicated four times. Original treatments (Bramble and Byrnes, 1974) consisted of:

A. Unsprayed control, with woody plants recut as needed in 1958, 1967, and 1976.
B. Broadcast foliage spray (D + T) of 2,4-D (2,4-dichlorophenoxy acetic acid) plus 2,4,5-T (2,4,5-trichlorophenoxy acetic acid) in water applied in summer 1953.
C. Semibasal spray of 2,4-D + 2,4,5-T in oil-water, applied as a selective stem-foliage spray in summer 1953.
D. Selective summer basal spray of 2,4-D + 2,4,5-T in fuel oil in summer 1953.
E. Selective winter basal spray of 2,4,5-T in fuel oil in February 1954.
F. Broadcast foliage spray of AMS (ammonium sulfamate) in water in summer 1953.

In June 1954 (June 1955 for the winter basal treatment), one-half of each replication was given a follow-up basal spray of 2,4-D + 2,4,5-T in fuel oil.

In June and July of 1966, the entire ROW research area was resprayed where needed to control resurging trees. Because of low brush density, the spray treatments consisted of a selective basal and stump spray of 2,4-D plus 2,4,5-T in fuel oil applied at an average rate of 25 gallons per acre. Where patches of species such as sassafras had developed, a stem-foliage spray was applied with 2,4-D plus 2,4,5-T amines in water.

Methods

Development of vegetation on the ROW has been followed over a 30-year period by taking abundance and cover value and sociability (Braun-Blanquet, 1932) on rectangular plots that were 33 feet wide and extended across the entire ROW (Bramble and Byrnes, 1955). One plot, located at random in each treatment replication, was checked carefully for representation of the plant community present by the expanding plot method described by Braun-Blanquet (1964).

The abundance-cover values (A) have been converted to the percent cover values listed below.

Abundance and Cover Class Symbols (A):		**Median Cover Value %**
+ +	= occasional	
+	= sparse, cover very small, less than 5% of the area	0.1
1	= plentiful, but of small cover value less than 5% of the area	2.5
2	= covering 5 to 25% of the area	15.0
3	= covering 25 to 50% of the area	37.5
4	= covering 50 to 75% of the area	62.5
5	= covering more than 75% of the area	87.5

Sociability Symbols (S):

1 = growing singly, one in a place
2 = grouped or clumped
3 = growing in small patches or cushions (troops)
4 = growing in large patches, small colonies, or carpet-forming
5 = large crowds, very extensive patches

Sociability reflects the gregariousness of a species which is fixed in only a few plants by their life form. As sociability is strongly influenced by site conditions and competition, it permits evaluation of the developmental condition of plant cover.

Abundance-cover (A) and sociability (S) were recorded in a combined value. For example, an A.S of 3.3 indicates that a species covers 25% to 50% of the ground area and grows in small patches. The medium cover value would be 37.5%

When cover values for various species on the ROW are summed, they may often total more than 100 percent. Layering of vegetation and the intermingling of foliage in any one layer is commonly encountered to produce such a high cover summation. This also has been reported by investigators using other estimation techniques (Rusch et al., 1980).

Scientific names of plant species are shown in the Appendix.

Results

Control of Target Species

A necessary and important part of the study of effects of herbicides on wildlife food and cover was the control of species capable of interference with transmission of electric power (target species). Thorough and careful applications of herbicides were necessary to get acceptable control and to cause disturbances typical of the different herbicide applications.

Excellent control of target species was obtained by all of the 1953 spray applications (Treatments B-F) which reduced living plants over 3 feet in height in 1957 to 133 per acre (Table 1). On the winter basal-sprayed areas (Treatment E), sassafras suckered vigorously to produce 1,182 plants per acre as compared to 1,282 plants per acre on handcut areas (Treatment A).

No retreatments were needed until 1966 when selective basal and stump sprays were applied over the entire ROW, regardless of previous treatments, plus a stem-foliage spray on sassafras patches. Excellent control was obtained, especially on sassafras, so that

by 1969 living plants over 3 feet in height averaged 46 per acre on spray treatment areas.

The number of target plants gradually increased until by 1973 they averaged 185 plants over 3 feet in height per acre on sprayed areas and 908 on the handcut areas. By 1980, the number of living plants over 3 feet in height per acre increased to an average of 612 for sprayed areas; there were 1,518 per acre on handcut areas (Table 1, Figure 1). The wide variation in number of trees that existed between replications was indicative of the irregular resurge pattern on the ROW at that time.

Relative abundance of species in 1957, expressed as a percent of the total number of plants, was as follows: sassafrass 69%, misc. oaks 12%, red maple 5%, bear oak 5%, and misc. hardwoods 9%. This had changed considerably by 1981 when the distribution was: misc. oaks 22%, red maple 21%, witch-hazel 21%, bear oak 17%, sassafras 12%, black cherry 5%, and misc. hardwoods 2%.

Height growth of trees on the handcut areas during the first year after cutting averaged 3 to 4 feet. In subsequent years, height growth averaged 1.5 to 2.0 feet per year between cuts in 1958, 1967, and 1976. Trees reached a maximum height of 14 to 16 feet prior to each recutting.

General Development of Vegetation

Vegetation present before ROW clearance was a typical upland oak-hickory forest in central Pennsylvania dominated by oaks (white oak, chestnut oak, red oak, and black oak) and a few hickories. Oak forests represent the most extensive forest type in the United States and cover about 125 million acres. Red maple, sassafras and black cherry were present as companion species. A very sparse shrub layer, over 5 feet in height, was dominated by witch-hazel, sassafras, and bear oak (Figure 2). A sparse ground layer, under 5 feet, contained as common shrubs: blueberry, huckleberry, deerberry, and teaberry. Blackberry, dewberry, sweetfern, and azalea were present but sparse. Bracken, vernal sedge, wild sarsaparilla, loosestrife, and panic grasses were common herbaceous species. Meadow fescue and mountain rice were occasional species. Total shrub cover value in the forest ranged from 7.5% to 22.6%; total herbaceous cover ranged from 17.9% to 20.0%.

A general overview of vegetation development on the ROW may be obtained from the progressive changes in shrubs and herbaceous plants occurring from 1953 through 1981 (Table 2 and Figure 3). Here and elsewhere, "blueberry" includes two species of blueberry and huckleberry.

Initial baseline data taken in 1953 before spraying indicate that a relatively uniform floristic composition existed on all ROW treatment areas. Blueberry, huckleberry, witch-hazel and teaberry, which were common shrubs of the former forest before clearance, had spread to become the common and dominant shrubs of the ROW. Bracken, vernal sedge, whorled loosestrife, and wild sarsaparilla of the former forest had become common and dominant herbs. The mean shrub cover was 14.4 percent; the mean herbaceous cover was 31.2 percent.

After spray treatments in 1953, which reduced target species to an average of 133 plants per acre, a marked drop in shrub cover took place on broadcast D + T (B) and AMS (F) and stem-foliage (C) treatment areas to a mean cover value of 3.3 percent (Figure 3). At the same time, shrub cover of the handcut controls (A) increased slightly from 12.2 to 16.8 percent. Shrub cover on the selective basal-sprayed areas (D and E) dropped from 18.0 to 11.1 percent.

Three shrub species that grew sparsely in openings in the former forest spread aggressively on the ROW to become dominant species by 1968 (Table 2). These were sweetfern, blackberry, and dewberry. Although the development of these species was more rapid on broadcast sprayed areas, they also became dominants on selective basal-sprayed areas.

A marked increase in herbaceous cover in 1954 was brought about by fireweed which suddenly appeared as a temporary cover wherever sprays had killed the vegetation. Fireweed practically disappeared by 1957 but reappeared for a brief period after the 1966 spraying of patches of sas-

Table 1. Control of target species on the ROW. Each value is an average of 4 replications. Sprays were applied in 1953 and 1966 (see Methods).

Date	Treatment	Oaks	Red maple	Black cherry	Misc. hdwds	Sassafras	Bear oak	Witch-hazel	Total
		No. living plants over 3 ft. ht. per acre							
1957	A	408	158	-	288	1282	126	-	2262
	B	14	-	-	2	4	24	-	44
	C	2	8	-	14	2	2	-	28
	D	4	8	-	8	124	14	-	158
	E	28	2	-	4	1182	8	-	1224
	F	0	10	-	16	0	2	-	28
							Average B-F		133
1969	A	276	74	0	2	2	116	36	506
	B	2	0	0	0	0	36	6	44
	C	2	4	0	0	0	40	0	46
	D	2	0	2	0	2	22	26	54
	E	0	0	0	0	0	14	30	44
	F	2	0	2	0	0	12	26	42
							Average B-F		46
1980	A	630	238	56	14	32	256	292	1518
	B	34	216	16	4	44	98	36	448
	C	66	166	64	22	52	80	64	514
	D	112	78	22	16	66	96	116	622
	E	105	75	3	3	317	186	133	822
	F	50	178	40	2	26	26	326	654
							Average B-F		612

Table 2. Changes in dominant species on handcut, broadcast, and selective basal treatment areas in late summer from 1953 through 1981. All original treatments were followed by selective maintenance. Abundance and sociability classes are given in brackets (see Methods).

Treatments	1953 before treatment	1954	1957	1968	1977	1981
Handcut in 1958, 1967, 1976	blueberry(2.2) bracken(2.1) sedge(+.1) loosestrife(2.1)	blueberry(2.3) bracken(1.1) sedge(+.1) loosestrife(1.1)	blueberry(2.2) bracken(3.2) sedge(2.3) loosestrife(1.2)	blueberry(4.3) bracken(1.1) sedge(1.2) loosestrife(+.1)	blueberry(4.3) dewberry(2.4) sweetfern(2.2) bracken(2.1) sedge(1.2) loosestrife(2.1)	blueberry(3.1) dewberry(1.3) witch-hazel(2.1) teaberry(1.1) bracken(2.3) sedge(1.3) hayscented fern(1.4) panic grass(2.2) sarsaparilla(2.1)
Broadcast D+T	blueberry(2.2) bracken(2.3) sedge(2.3) loosestrife(2.1)	bracken(1.1) sedge(2.2) loosestrife(1.1) fescue(2.4) fireweed(1.3) panic grass(2.3)	bracken(2.4) sedge(2.2) loosestrife(1.1) fescue(2.4) fireweed(1.3) panic grass(2.3)	sweetfern(3.4) blueberry(2.3) bracken(3.4) sedge(2.3) loosestrife(+.1) fescue(2.4) goldenrod(2.2)	blackberry(3.4) blueberry(3.3) sweetfern(2.2) bracken(2.1) sedge(1.2) fescue(2.4) goldenrod(2.3) hayscented fern(2.4) sheep sorrel(2.3)	blackberry(4.5) blueberry(2.3) dewberry(2.4) sweetfern(2.1) teaberry(1.1) bracken(2.1) fescue(2.4) goldenrod(1.1) hayscented fern(2.4)
Summer basal D+T	blueberry(2.2) bracken(2.3) sedge(2.3) loosestrife(1.1)	blueberry(1.2) bracken(3.3) sedge(1.3) loosestrife(1.1) fescue(1.4) panic grass(1.2)	blueberry(2.2) bracken(2.2) sedge(2.3) loosestrife(2.1) fescue(1.4) panic grass(2.2)	sweetfern(2.4) blueberry(2.3) dewberry(2.4) bracken(3.3) sedge(2.3) loosestrife(+.1) fescue(2.2) goldenrod(2.2) panic grass(1.2)	blueberry(3.3) blackberry(2.4) dewberry(2.4) sweetfern(2.2) bracken(2.1) fescue(2.4) goldenrod(2.4) hayscented fern(2.4) panic grass(1.2)	blueberry(2.4) blackberry(2.4) dewberry(2.4) sweetfern(2.1) teaberry(1.1) witch-hazel(2.2) bracken(+.1) fescue(2.5) goldenrod(2.4) hayscented fern(1.4)

safras on winter basal treatment areas.

Bracken, vernal sedge, and whorled loosestrife remained common herbs on the ROW on all sprayed areas and controls and thrived until 1980-81 when they decreased sharply owing to shrub and tree competition. Tall meadow fescue, a sod-forming grass, remained in large patches on a few certain areas irrespective of treatment. By 1968-'81, herbs favored by open conditions, such as goldenrods and hayscented fern, developed to become important ROW species.

Shrub species became the dominant vegetation on the ROW by 1980-81. These were blueberries and huckleberry, blackberry, teaberry, witch-hazel, and dewberry. Sweetfern had retrogressed and appeared mostly as single plants and groups rather than large patches typical of its peak development in 1965-1968.

Herbaceous species, in general, decreased by 1980-81 when the ROW plant cover assumed a typical mosaic pattern of shrub patches with small herbaceous openings. Also at that time, tall-growing trees, notably red maple, black cherry, and red oak, had developed to a point where control measures were needed to protect transmission wires (Figure 4).

Thus, in 1981, 30 years after ROW clearance, the typical vegetation on all areas was a complex mixture of species derived from the early blueberry-bracken-sedge-loosestrife community plus aggressive species typical of openings (Table 2, Figure 5). Blackberry, blueberries and huckleberry, dewberry, sweetfern, witch-hazel, and teaberry were important shrubs. These were intermingled with herbaceous species the most common of which were goldenrods, bracken, vernal sedge, hayscented fern, sheep sorrel, and wild sarsaparilla. On a few areas, tall meadow fescue was an important species, which formed large patches of heavy sod. This community formed a tight cover resistant to tree invasion and desirable for the many wildlife species using the ROW. It appeared to represent a proclimax stage in plant succession which may be maintained by repeated removal of trees that will prevent development towards the former oak-hickory forest.

Several importnt features are worth emphasizing in this general summary of vegetation development. In Table 2, the succession of dominant species from 1953 to 1981 indicates that plants of openings gradually became major dominants. Typical forest plants (blueberries and huckleberry, bracken, sedge, and loosestrife) were the sole dominants for about 5 years. Subsequently, sweetfern, which is a shrub of forest openings, spread rapidly to become a dominant species by 1965. This was later accompanied by goldenrods, which became dominant later in 1968. Blackberry, an aggressive shrub of openings which was sparse on the ROW in early years, became the major dominant by 1977. Similarly, dewberry and hayscented fern, also sparse in early years, became major dominants growing in large patches.

In Figure 3, the trend for total cover development of both shrubs and herbaceous plants was similar on all treatment areas. After a drop in 1954, total shrub cover gradually increased until a sharp drop occurred in 1977. This drop coincided with an increase in tree cover. Total herbaceous cover also increased followed by a drop in 1977 when shrub and tree cover suppressed many species.

Species Density and Richness

The number of species found within bounded plots on each treatment unit (species density) provided an important measure of the effects of the various treatments on ROW vegetation. Also important was the total number of species present on each treatment area (species richness).

Shrub species—Density of shrub species in 1953 had a narrow range of 8.8 to 10.0 on sample plots of areas to be treated (Table 3). The total number of shrub species present (species richness) ranged from 10 to 14.

After spraying in 1954, species density of shrubs dropped by 4.0 on the broadcast D + T-sprayed areas; 4.4 on the AMS broadcast-sprayed areas; and 3.0 on the stem-foliage-sprayed areas. On the other hand, species density dropped by only 1.8 to 2.2 on the winter and summer basal-sprayed areas.

Figure 3. Trends in development of total shrub and herbaceous cover on handcut (Treatment A), broadcast (Treatment B), and summer basal (Treatment D) from 1953 through 1981.

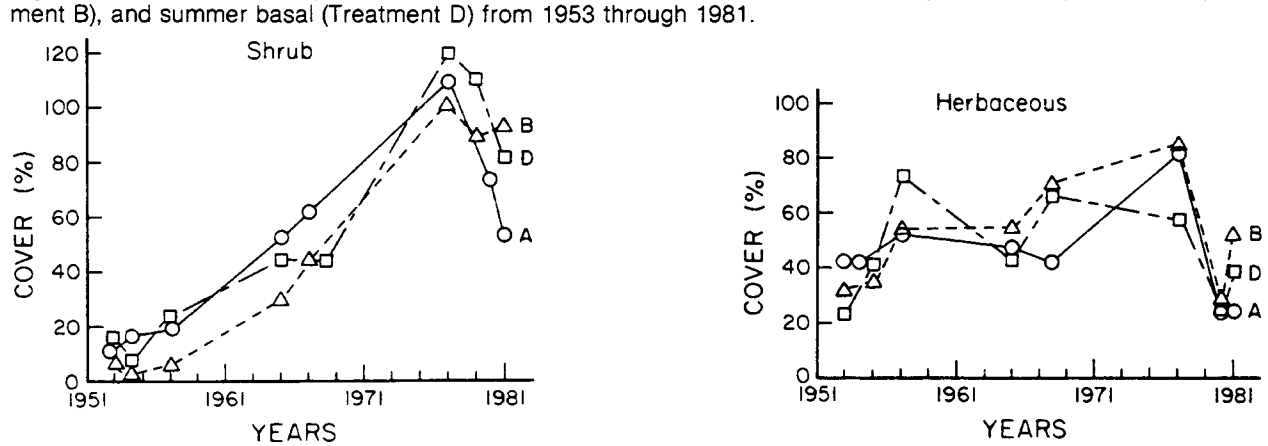

Figure 1. Handcut area in 1981 (IA) with 12-14 feet height oak and maple sprouts, 1312 plants per acre.

Figure 2. Adjoining forest with a ground layer of bracken, sedge, loosestrife, and blueberry; and a sparse witch-hazel shrub layer (ID).

Figure 4. Selective basal area (IID) in 1981 with trees 10-12 feet height, and witch-hazel in clumps. An herbaceous opening dominated by goldenrod is in the foreground.

Figure 5. ROW proclimax community, formed in 1973, dominated by blackberry, blueberry, dewberry, sweetfern, and witch-hazel with bracken, goldenrod, and hayscented fern (IID).

When differences between the means of 1953 and 1954 were analyzed by the t-test for independent samples at the 5% level, only species density on the two broadcast areas had changed significantly. Total number of species (richness) ranged from 8 to 11 for all areas, and a number of species had disappeared from both the broadcast- and basal-sprayed areas. These included maple-leaved viburnum, black chokeberry, hazelnut, deciduous holly, and azalea, Dewberry and deerberry were absent only on the broadcast areas. The common shrubs blueberries, huckleberry, witch-hazel, bear oak, and teaberry were present on all areas.

By 1981, with selected maintenance during the intervening years, species density of shrubs was again similar on all treatment areas (Table 3). Species density ranged from 7.5 to 10.5, with 8.8 on the handcut areas. Total species ranged from 13 to 17 on sprayed areas, with 14 on the handcut areas. Maple-leaved viburnum and hazelnut were still missing on all sprayed areas with azalea present only on the basal-sprayed areas. Low-growing trees, serviceberry and hawthorn, were present on both broadcast- and selective basal-sprayed areas.

Herbaceous species—The herbaceous species density before spraying in 1953 ranged from 14.5 to 19.5 on plots of areas to be treated (Table 3). Total number of species present (species richness) ranged from 14 to 19.

In 1954, species density had dropped by 7.2 on broadcast-sprayed areas, 3.3 on AMS broadcast-sprayed areas, and 1.5 to 3.0 on selective summer and winter basal-sprayed areas. Total number of species present ranged from 11 to 16 on sprayed areas, with 14 on handcut controls. Most of the common species were still present after spraying on all treatment areas. These included bracken, vernal sedge, whorled loosestrife, panic grasses, meadow fescue, sheep sorrel, and mountain rice. Fireweed became an important temporary cover on all broadcast-sprayed areas while on selective basal-sprayed areas it occurred in only a few spots that had been disturbed. When the differences between means for 1953 and 1954 were compared by the t-test at the 5% level, only herbaceous species density on the broadcast D+T areas had dropped significantly.

Table 3. Comparison of species density (number of species per plot) and species richness (total number of species present) on treatment areas before spraying in 1953 and later in 1954 and 1981.

Treatment	Life Form	1953 Density	1953 Richness	1954 Density	1954 Richness	1981 Density	1981 Richness
Handcut	Shrub	9.8	14	8.3	10	8.8	14
	Herbaceous	19.5	19	17.0	14	13.8	27
	Total	29.3	33	25.3	24	22.6	41
Broadcast D+T	Shrub	8.8	10	4.8	9	8.5	14
	Herbaceous	18.2	17	11.0	16	13.0	19
	Total	27.0	27	15.8	25	21.5	33
Stem-foliage D+T	Shrub	10.0	13	7.0	10	9.5	13
	Herbaceous	14.5	15	11.3	11	12.0	17
	Total	24.5	28	18.3	21	21.5	30
Summer basal D+T	Shrub	9.5	11	7.3	9	9.5	14
	Herbaceous	15.0	17	13.5	12	10.3	18
	Total	24.5	28	20.8	21	19.8	32
Winter basal T	Shrub	9.5	12	7.7	11	10.5	17
	Herbaceous	17.8	17	14.8	16	12.0	24
	Total	27.3	29	22.5	27	22.5	41
Broadcast AMS	Shrub	9.2	12	4.8	8	7.5	13
	Herbaceous	15.8	14	12.5	12	14.1	22
	Total	25.0	26	17.3	20	21.6	35

By 1981, after subsequent selective maintenance, the species density was again similar on all spray treatment areas (Table 3). Species density ranged from 10.3 to 14.1 , with 13.8 for the handcut areas. Total number of species present on sprayed areas ranged from 17 to 24, with 27 on handcut controls. Goldenrods and hay-scented fern had developed into dominant cover on all spray areas.

Similarity of Vegetation on Treatment Areas

The degree of similarity of vegetation on sprayed treatment areas versus unsprayed controls was used as a nonparametric approach to a comparison of treatment effects. Although it was necessary to recut the controls at 9-year intervals to prevent trees from growing into the danger zone under the transmission wires, they did prove to be valuable for a number of comparisons including the degree of species cover similarity with spray areas.

A modification of a well-known "quotient of similarity" (Sorensen, 1948) was used to compare the degree of similarity of species cover values with the handcut control. This quotient (QS) expresses the similarity between quantities (cover values) in two populations (ROW treatment areas) and is calculated by the formula: $QS = 2W/A+B \times 100$, where w = the sum of the smaller cover values of each species in two treatments, A = the sum of the cover values of species in one treatment, and B = the sum of the cover values of species in the second treatment. Each cover value represented the average of 4 replications of each treatment and only the common species that produced significant cover were used in the calculations. Cover values were calculated from field estimates using the median values for each cover class described under "Methods," which expressed the relative contributions to ROW cover made by individual species. A threshold of 40 percent was taken as the separation between similarity and dissimilarity. This agrees with the threshold propos-

Table 4. Grid comparison of the quotient of similarity (QS) for species cover values of each treatment with all of the others in 1981.

Herbaceous

Treatment	A	B	C	D	E	F
			QS %			
A	-	36	47	35	48	51
B	36	-	70	61	40	60
C	47	70	-	33	52	69
D	35	61	33	-	49	47
E	48	40	52	49	-	61
F	51	60	69	47	61	-
Av.	43.4	53.4	54.2	45.0	50.0	57.6

Av. all comparisons 50.6 av. ± 5.5 SD

Shrub

Treatment	A	B	C	D	E	F
			QS %			
A	-	71	88	74	90	73
B	71	-	83	68	66	78
C	88	83	-	76	83	77
D	74	68	76	-	72	68
E	90	66	83	72	-	61
F	73	78	77	68	61	-
Av.	79.2	73.2	81.4	71.6	74.4	71.4

Av. all comparisons 75.2 av. ± 4.2 SD

ed as a guide by Mueller-Dombois and Ellenberg (1974) and used by Sorensen (1948). It is used herein as a convenient point of reference for comparison of similarities.

Similarity in herbaceous cover—A close similarity (QS 66 to 72%) existed in 1953, before spraying, in species cover between all units to be treated with herbicide sprays (Figure 6). The dominant species used in QS calculations were bracken, vernal sedge, whorled loosestrife, wild sarsaparilla, meadow fescue, fireweed, goldenrod, hayscented fern, panic grasses, poverty grass, sheep sorrel, and mountain rice.

In 1954, after spraying, the selective basal areas (Treatments D and E) were still highly similar to the controls (A), with QS of 67% and 72%. The broadcast AMS- and stem-foliage sprayed areas (F and C) were dissimilar with QS of 36% and 20%. The broadcast D+T sprayed areas (B) were similar to the handcut controls (QS 52%) owing to high cover values for sedge and panic grasses.

By 1957, 5 years after spraying and just prior to recutting of controls in 1958, all spray areas had become similar to the controls. The QS for selective basal-sprayed areas were 76% and 78%; the QS for stem-foliage-sprayed areas was 69%; and the QS for broadcast-sprayed areas was 42% and 49%.

In 1981, 29 years after original spraying and just prior to recutting of controls in 1982, all spray areas were nearly uniform and reasonably similar to the controls with QS ranging from 35% to 51%. The cause for low similarities of all treatments was a decrease in herbaceous cover in the controls caused by dense tree cover just prior to cutting and the presence of large patches of fescue on treatments B and D. However, when a further comparison was made of the cover values of each treatment with the sum of all others, the average QS ranged from only 43.4% to 57.6% with an overall average QS of 50.6 ± 5.5% for all treatment comparisons (Table 4). This indicates a relative homogeneity in species cover on the ROW in a proclimax community composed of forest shade species mixed with plants of openings. This plant community could be maintained, with some minor cycles, through continued selective removal of trees. Relative dominance of individual species, however, will probably change from time to time in response to natural changes in climatic and biotic factors.

Similarity in shrub cover—The degree of similarity between cover values for a constant group of dominant shrubs was compared for each spray treatment with the controls. The species used were blackberry, blueberries and huckleberry, dewberry, sweetfern, teaberry, and witch-hazel.

In 1953, before spraying, the units to be treated were highly similar to the controls (A) with QS ranging from 61% to 90% (Figure 6).

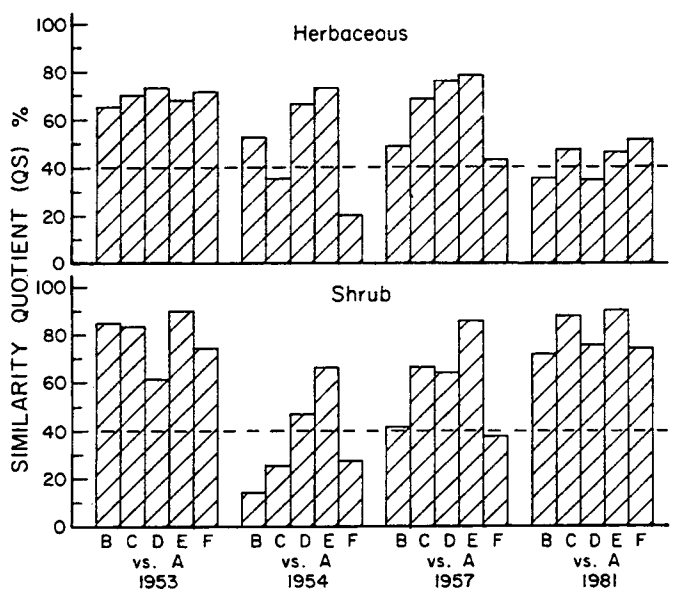

Figure 6. Similarity of cover values on treatment areas compared to unsprayed controls before spraying in 1953 and after spraying in 1954, 1957 and 1981. A = handcut control, B = broadcast D+T, C = stem-foliage, D = summer basal, E = winter basal, F = broadcast AMS. The similarity quotient (QS) was obtained by comparing each spray treatment with the control using the formula:

$$QS = \frac{2W}{A+B} \times 100.$$

In 1954, after spraying, the shrub cover on broadcast- and stem-foliage-sprayed areas (B, F and C) were not similar to the controls with QS ranging from 13% to 28%. Loss of blueberry was a major factor in causing this dissimilarity. The selective basal-sprayed areas (D and E) were similar to the controls with QS of 47% and 67%.

In 1957, 5 years after spraying and just prior to recutting of controls in 1958, all spray areas except the broadcast AMS (F) had become similar to the controls with QS ranging from 41% to 86%. The broadcast AMS-sprayed areas were still slightly dissimilar with QS of 38% owing to a low cover value for blueberry.

In 1981, 29 years after the original spraying and just prior to recutting of controls in 1982, all of the spray areas were similar in shrub cover to the controls with QS of 71% to 90%. This high similarity in species cover indicated a homogeneity within the ROW plant community at that time.

A further test of similarity in 1981 was made by comparing each set of treatment areas with the sum of all others (Table 4). The average QS for this comparision ranged from 71.6% to 81.4% with an average of 75.2 ± 4.2%. It appears, therefore, that a relatively homogeneous proclimax plant community has developed on the ROW.

Development of Nontarget Species

Strategies and development of common shrubs

Growth habits and methods of reproduction of shrub species on the ROW are valuable keys to their patterns of development and to the strategies used to gain dominance (Grime, 1979). Of special interest is their ability to spread vegetatively by rhizomes and rhizomatous roots. Rhizomes are special underground stems that can produce both stems and roots at their nodes (Figure 7 and 8).

Successful development of nontarget shrubs on ROWs is considered a highly important objective of ROW management that has been stressed by several investigators (Egler, 1975; Niering and Goodwin, 1974). While it appears that there are cases where certain shrub communities are relatively permanent and highly resistant to tree invasion, these usually occur under special conditions of habitat such as sites highly unfavorable for trees, or where human and animal disturbance and fire are continuous. Scrub oak barrens in central Pennsylvania are typical examples of the latter conditions.

Shrub species common on the ROW under study varied considerably in their stability and resistance to tree invasion (Bramble and Byrnes, 1976). For example, shrubs such as sweetfern and blackberry were open to invasion by red maple and black cherry. And, although dense patches of low early blueberry were highly resistant to tree invasion, the more open patches of huckleberry typical on the ROW were not resistant. It appears, therefore, that although shrub cover is a valuable component of ROW vegetation that is needed to produce the desired mix of shrub patches interspersed with herbaceous openings, shrubs in general should not be overrated as deterrents to tree invasion. A shrub stage often is forerunner to a forest stage in secondary plant succession.

The following are important characteristics of the common shrubs found on the ROW and their typical development:

Blackberry—This shrubby perennial, often referred to as a cane plant, is commonly found in openings, clearings, burns, and other disturbed areas. It produces abundant fruit, and its seeds, which are distributed widely by birds and other wildlife, may accumulate as a seed bank in the forest floor to produce dense stands after clearance (Graber and Thompson, 1978). New stems are produced each year from perennial rhizomatous roots. These stems are biennial and often reached heights of 7 to 8 feet on the ROW where they formed large patches that were difficult for man to penetrate but were frequented by wildlife. Blackberry is a highly aggressive species that invaded and overtopped other shrubs such as sweetfern on the ROW (Figure 9). Blackberry patches, in turn, were invaded successfully by trees (Bramble and Byrnes, 1976).

Blackberry typically appeared as a sparse single plant of low cover value (Abundance and Sociability, A.S of +.1) on the ROW after spray treatments (Table 2 and Figure 10). It then spread aggressively so that by 1977 it became a major dominant on all treatment areas (A.S of 3.4) and continued to increase through 1981 (A.S of 4.5). The handcut areas with dense tree cover differed from this pattern as blackberry remained sparse or absent (A.S of +.1) on them.

Blueberries and huckleberry—These low shrubs typically grow in dry, open woods, thickets, barrens, clearings, and burns where they spread vegetatively by rhizomes (Figure 7) to form dense patches, often in pure clones. Such patches have been highly resistant on ROWs to tree invasion (Bramble and Byrnes, 1976; Niering and Goodwin, 1974). Although blueberries have been subject to severe frost damage on the ROW in certain years, they usually produce abundant fruit. Both species of blueberry were common in the forest (A.S of 2.2) before treatments (Table 2). On broadcast- and stem-foliage-sprayed areas, blueberry cover dropped sharply after the spraying in 1953 to sparse single plants (Figure 10) (A.S of +.1). Under selective maintenance, however, blueberry cover gradually increased so that by 1968 it was nearly equal to selective basal-sprayed areas (A.S of 2.3). Owing to damage around sprayed trees a drop also occurred in blueberry cover on summer basal-sprayed areas, while blueberry cover on winter basal-sprayed areas remained stable and similar to the handcut areas. Huckleberry was not seriously affected by sprays.

Dewberry—This prostrate, evergreen shrub is commonly found on moist sites and bogs but may also occur in dry, open woods or swales. Dewberry produced fruit on the ROW and has spread to

Figure 7. Rhizomes typical of low early blueberry enable it to spread vegetatively to form dense patches.

Figure 8. Rhizomes of hayscented fern enable it to spread and form dense patches.

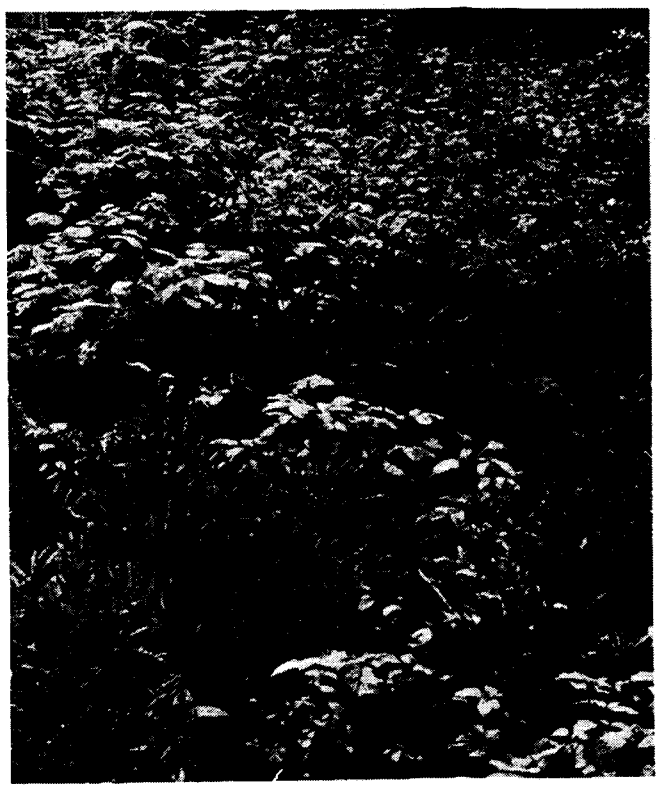

Figure 9. Large patch of sweetfern invaded by blackberry in 1977 (IV D).

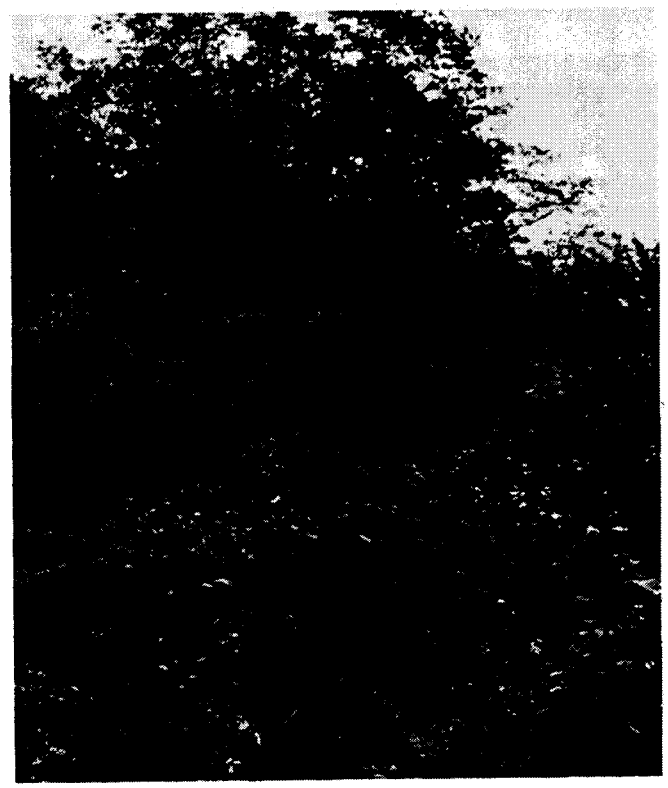

Figure 11. Bear oak and witch-hazel edge in 1979 (IV B). A typical mixture of blackberry, blueberry, and sweetfern with bracken, sedge, loosestrife, and goldenrod is in the foreground.

form large patches that appear resistant to tree invasion. Its trailing stems may reach 4 feet long and form roots at their tips to spread vegetatively. The numerous runners may then interlace to form dense mats.

Dewberry was unusual in that it remained absent or sparse (A.S of +.1) on all sprayed areas through 1968. It then increased rapidly to form large patches of evergreen cover under other species and in openings in the shrub cover (A.S of 2.4).

Scrub or bear oak—This shrub, or low tree, is usually found as a low straggly shrub from 3 to 10 feet in height but may grow to 20 feet as a small tree. It occurred in openings in the oak forest before clearance and was also common in the region on broad mountain tops and in scrub oak barrens covering extensive areas which are maintained by fire. On the ROW, it produced abundant and consistent acorn crops and formed dense shrubby edges (Figure 11).

Bear oak was treated as a target species in 1953 but was regarded later in maintenance sprays as nontarget as it remained a low straggly shrub. Bear oaks appeared as sparse single plants (A.S of +.1) in 1953 but later became an important shrub on most sprayed areas (A.S of 1.2 to 2.3).

Sweetfern—This aromatic shrub was found in small openings in the oak forest before ROW clearance. It is typical in burns, clearings, pastures, and scrub oak barrens. Seeds are borne in bur-like catkins which produce four nutlets that fall to the ground in August and September. Sweetfern also spreads vegetatively by thick, woody rhizomes which enabled it to form large, dense patches on the ROW at its peak development when it reached heights of 4 to 5 feet. Sweetfern was only moderately resistant to tree invasion and was commonly invaded by red maple (Bramble and Byrnes, 1976).

Sweetfern first appeared as sparse single plants (A.S of +.1) on the ROW (Figure 10). It spread rapidly, so that by 1965 to 1968 it had become a dominant species in large patches on the ROW on all sprayed areas (A.S of 2.4 to 3.4) (Table 2). It then began to deteriorate and decreased in cover value, as well as sociability, to grow singly or in small groups of low to medium cover value (A.S of 1.1 to 2.2). Sweetfern patches were aggressively invaded by blackberry and goldenrod as they deteriorated (Figure 9). This deterioration bears a striking similarity to cyclic tendencies reported for bracken-heather in the British Isles by Watt (1955) where four stages of heather were recognized in 30-year-old stands: pioneer, building, mature, and degenerate.

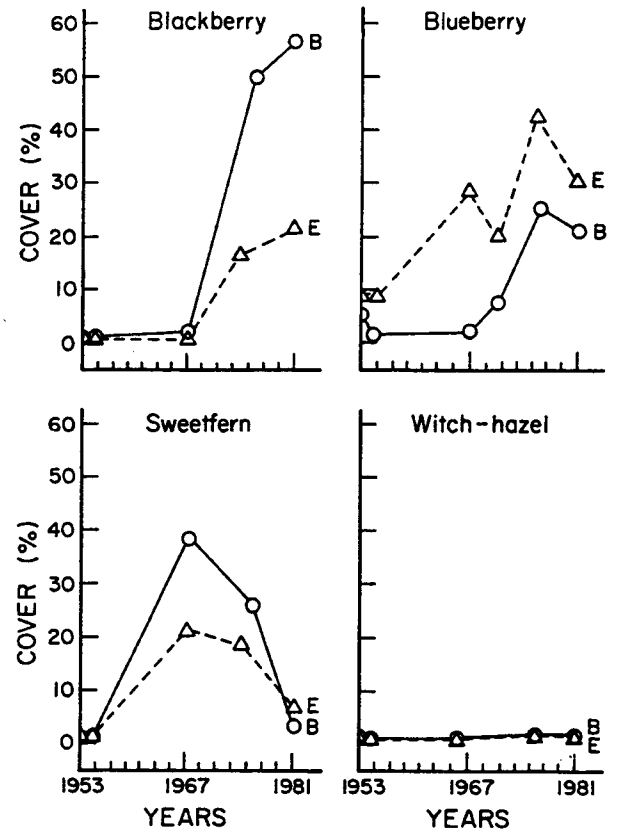

Figure 10. Examples of long-term developmental patterns on broadcast D+T (Treatment B) areas and summer basal (Treatment E), followed by selective maintenance. Cover percent is the average of 4 replications. Blackberry was highly eruptive, blueberry gradually increased, sweetfern was eruptive and then degenerative, and witch-hazel was consistently sparse.

Teaberry—This small evergreen shrub commonly grows in dry woods and clearings. The slender stems are extensively creeping on or below the surface of humus layers of the forest floor and send up erect shoots to about a 5-inch height.

Teaberry was abundant but of low cover value (A.S of 1.1) on the ROW before spraying in 1953. It subsequently remained as a sparse component of ROW vegetation (A.S of +.1 to 1.1), and maintained its highest cover value at ROW-forest edges.

Witch-hazel—This tall shrub formed a thin understory in the oak forest before clearance. Witch-hazel flowers in the fall, and reproduction is by small, shiny seeds which are expelled from capsules in the fall. Although it reached a height of 18 feet in openings in the adjoining forest and was treated as a target species in 1953, it has remained a bushy shrub on the ROW with a height of only 10 to 12 feet. Witch-hazel frequently produced thicket-like edges on the

ROW (Figures 11 and 12). From 1977 to 1980, it increased in cover value on a few certain areas (A.S of 2.2).

There also were other low tree, shrub and woody vine species that remained of minor value as plant cover on the ROW. They are listed below along with the treatment areas on which they were found:

	Treatment areas on which found
Arbutus, trailing	A B C D E F
Azalea	A B C D E F
Chokeberry, red	A C D E F
Chokeberry, black	B D
Bush honeysuckle	A C
Deciduous holly	C D E F
Deerberry	A B C D E F
Flowering dogwood	A
Gooseberry	A B E
Grape	F
Hazelnut	B D E F
Hawthorn	A B C D E F
Mountain holly	D E
Mountain laurel	A B C D E F
Sawbrier	E
Serviceberry	C E F
Viburnum, dentate	E

Three intermingling ROW vegetation layers, of which shrubs were an important component, could be recognized by 1977 to 1981.

(1) A tall shrub layer ranging from 5 to 12 feet in height composed of witch-hazel and bear oak.

(2) A medium layer ranging from 3 to 8 feet in height containing blackberry and sweetfern, with goldenrods.

(3) A ground layer ranging to 3 feet in height containing blueberries and huckleberry, dewberry, teaberry, bracken, loosestrife, hayscented fern, vernal sedge, panic grasses, wild sarsaparilla, and sheep sorrel as common species.

The change in total shrub cover is important to long-term ROW management, and two features of shrub development should be recognized: (1) that an increase in shrub cover as a percentage of total plant cover occurred, and (2) that this increase was relatively slow. A similar situation was reported from an 18-year study of roadside vegetation in Wisconsin (Rusch, Thompson, and Kabat, 1980). Development of a dominant shrub cover from a shrub-herb community agrees with the normal sequence of plant development expected on moderately moist sites in the region (Niering and Goodwin, 1974). It is part of a complex plant succession from forbs to shrubs to trees. This slow but eventual development of shrub cover to be expected under selective removal of target trees should be recognized in ROW management. However, also to be taken into account, is the probability of considerable variations in this process as it proceeds, particularly in cases where certain shrubs such as blackberry and sweetfern may increase in an explosive manner from a slow beginning, or appear at once after ROW clearance from seeds accumulated in the forest floor.

Strategies and development of common herbaceous species.

"Herbaceous" has been used in this study to include all nonwoody plant species. These plants are capable of forming important low cover on ROWs and may be relatively stable (Egler, 1975; Bramble and Byrnes, 1976). After spraying in 1953, total herbaceous cover ranged from 37.0 to 41.0 percent on sprayed areas (Figure 3). This cover remained highly important through 1973 to 1977 although it decreased in 1980 to 25.0 to 28.0 percent as shrub and tree cover increased. On handcut areas, herbaceous cover remained relatively low and was subject to cyclic changes as a result of regrowth and subsequent recutting of all woody stems in 1958, 1967, and 1976.

The growth habits and strategies of common herbaceous species are important to an understanding of their specific patterns of development (Figure 13). Of special interest is their ability to spread vegetatively by means of underground stems or rhizomes. This strategy was typical of the common perennials on the ROW and permitted them to grow in dense patches, invade other species and to become important dominants.

Competitive strategies and development of common and important herbaceous species may be summarized as follows:

Bracken—This fern was an important herbaceous cover plant in the forest (A.S of 2.3) and persisted in this status on the ROW until suppressed by shrubs and trees in 1980-81 (Table 2 and Figure 5). It typically occurs in open woods, clearings, and burns. Bracken is a perennial that spreads by extensive, forking rhizomes which are very long-lived. In the winter, the fronds die and are matted down by rain and snow to form an effective barrier against tree invasion; in the spring, its vigorous new fronds push up through the dense litter.

Tall meadow fescue—This grass was an important cover (A.S of 2.4) on only one broadcast- and two selective basal-sprayed areas (Table 2). It commonly grows in meadows and open woods where it is a stable perennial grass that spreads by creeping rhizomes to form a dense sod that is highly resistant to tree invasion.

Fireweed—This tall, coarse herb is commonly found in clearings, burns, and damp thickets. Fireweed is an annual that spreads by abundant seeds on exposed soil and thus tends to lead to a "fugitive existence" by forming new colonies on newly disturbed areas. On the ROW, it often formed pure populations (A.S of 4.5) on AMS broadcast-sprayed areas and a few small patches on basal-sprayed areas (A.S of 1.3) which lasted but a few years (Table 2).

Goldenrods—These tall perennial herbs are usually found on moist open areas, in thickets, and on the borders of woods and swamps. They spread vegetatively by stout rhizomes and often reached 4 feet in height on the ROW. Goldenrods were agressive and grew up through deteriorating sweetfern. Rough goldenrod also has been recently reported as preventing black cherry reproduction through

production of plant auxins (allelopathy) (Horsley, 1977). On the ROW, goldenrods began as sparse, single plants (A.S of +.1) and gradually increased in cover value (A.S of 2.2 to 2.4) to become major dominants by 1968-1977 (Table 2 and Figure 13).

Hayscented fern—This fern is commonly found in pastures, damp slopes, and open rocky woods. It spreads vegetatively by extensive, creeping and forking rhizomes (Figure 8). On the ROW it has been killed back several times in certain locations by frost, most recently in 1980. Hayscented fern has been slow in developing and was not recorded on the sprayed areas until about 1968. Since that time it has spread to become a major dominant in large patches (A.S of 2.4) on many areas (Table 2 and Figure 12).

Whorled loosestrife—This medium herb of dry open woods and thickets is a perennial which spreads vegetatively by rhizomes. Although its importance as a cover plant varied during the 30 years, it was usually abundant but of low cover value (A.S of 1.1) (Table 2 and Figure 13).

Mountain rice—This harsh-leaved, tufted grass is typical of upland woods and thickets. It is a perennial which grew on the ROW as conspicuous single plants of low cover value (A.S of +.1).

Panic grasses—These two low panic grasses are commonly found in clearings and dry, open woods. They are perennials which usually grow tufted or in small groups, and are without elongate rhizomes. They reached their highest cover values (A.S of 2.3) during the grass-sedge stage, which followed broadcast D+T spraying, and after the 1966 foliage spraying of sassafras on winter basal areas (Table 2).

Poverty grass—This low grass is commonly found on dry abandoned fields and in thin woodlands. It is a perennial which forms an open tufted sod. On the ROW it was an important cover plant only on access roads.

Wild sarsaparilla—This low perennial herb, which is typical ground cover in moist woods, spreads vegetatively by long, thick rhizomes. Although it did not generally thrive on the ROW, it became numerous with relatively low cover value (A.S of 1.1) on a few areas where it appeared to be favored by the shade of trees and shrubs (Table 2).

Vernal sedge—This low tufted sedge is typical of open woods and open dry sites. It is a strongly stoloniferous perennial that was one of the early dominant plants on the ROW (A.S of 2.3) and retained that status until it was supressed by trees and shrubs (Table 2). It appeared most prominently in the spring before other cover developed.

Wildlife Food and Cover

The original impetus responsible for initiation of this project was the concern of sportsmen for the effects of herbicides on game. A major objective, therefore, was to investigate the effects of herbicide sprays on game food and cover. Later, this was expanded to include nongame species common to the area.

Frequent use of the ROW by wildlife was documented from the beginning (Bramble and Byrnes, 1972; Bramble, 1974), and agrees with use of ROWs by wildlife that has been reported on 22 ROWs in New York state (Asplundh Environmental Services, 1977). Common species that have used the ROW are:

Game mammals
- White-tailed deer (*Odocoileus virginianus*)
- Cottontail rabbit (*Sylvilagus floridanus*)
- Gray squirrel (*Sciurus carolinensis*)

Other small mammals
- Mice (*Peromyscus* spp.)
- Opossum (*Didelphis marsupialis*)
- Raccoon (*Procyon lotor*)
- Woodchuck (*Marmota monax*)

Game birds
- Ruffed grouse (*Bonasa umbellus*)
- *Wild turkey (Meleagris gallopavo*)

Raptors
- Red-tailed hawk (*Buteo jamaicensis*)

Songbirds
- American goldfinch (*Spinus tristis*)
- Black and white warbler (*Minotilta varia*)
- Blue jay (*Cyanocitta cristata*)
- Brown thrasher (*Toxostoma rufum*)
- Catbird (*Dumetella carolinensis*)
- Crow (*Corvus brachyrhyncos*)
- Field sparrow (*Spizella pusilla*)
- Hairy woodpecker (edge) (*Dendrocopos villosus*)
- Indigo bunting (*Passerina cyanea*)
- Magnolia warbler (*Dendroica magnolia*)
- Robin (*Turdus migratorius*)
- Yellow-rumped warbler (*Dendroica coronata*)
- Rufous-sided towhee (*Pipilo erythrophtalmus*)
- Song sparrow (*Melospiza melodia*)
- Starling (*Sturnus vulgaris*)
- Tree sparrow (*Spizella arborea*)
- Yellow-shafted flicker (*Colaptes auratus*)
- Yellowthroat (*Geothlypis trichas*)

These same avian species also have been reported by other investigators on ROWs in other parts of the Appalachian oak forest (Anderson, 1979; Carvell and Johnston, 1978; Chasko and Gates, 1979; Everett, Speake, and Maddox, 1979; Gates and Dixon, 1979; Lawson and Gates, 1979; LeGrand, 1971). These investigations have shown that songbirds, typical of shrubby habitats and edges, make considerable use of ROWs and are valuable additions to the birds of the adjoining forest. The acreage occupied by a 150- to 200-foot ROW traversing a large forested area is relatively small so that unless coupled with other disturbances, displacement of forest-inhabiting birds should have a minor effect on their total populations.

Shrubs as Wildlife Food and Cover

One of important values of shrubs on a ROW is their use by wildlife for food. Fruits of common shrubs were usually abundant on the study ROW, even though in a

few years certain species were prevented from fruiting by killing frosts. Blueberry appeared to be most often affected; and in 1981, even blackberry failed to fruit.

It was observed that species such as blueberry, which fruited only sparsely in the adjoining forest, fruited abundantly on the ROW. This was also true of witch-hazel and bear oak which had produced sparse fruit in the forest, mostly in openings, and made the shrubby edges formed by these species on the ROW highly valuable to wildlife (Figures 11 and 12).

Shrubs on the ROW browsed by deer were rated very high in both their utilization factor and feed value (Tables 5 and 6). Seasonal variation was important in that bear oak, witch-hazel, and blueberry, were heavily browsed on the ROW in all seasons of the year. However, sweetfern was browsed only in the winter and early spring, and blackberry was browsed only in the summer.

Shrub cover was important on the ROW for hiding and resting, as well as a place to rear young. The dense patches of sweetfern, blackberry, and witch-hazel were particularly important as they offered dense cover that was lacking in the forest (Figure 12). Wildlife trails and deer beds were commonly observed in such patches. Songbirds sought tall shrubs for escape cover when disturbed, and escape and loafing cover was provided for deer on the ROW edges of witch-hazel and bear oak.

Shrub cover on the ROW was used by wildlife in rearing their young. For example, the low dense cover provided by sweetfern and blueberry was used by deer for concealment of fawns, which were frequently flushed in early summer. Nests of songbirds were commonly located in shrub cover, particularly in dense blackberry favored by towhee and goldfinch, and in witch-hazel used by catbird and robin.

Wildlife utilization of common shrubs

Bear oak—Acorns of bear oak produced abundantly each year on the ROW are an important food of many wildlife species (Martin et al., 1951), and were an important supplement to the more erratic crops produced by other oaks in the adjoining forest. This is particularly important to the deer herd that is dependent in large part upon acorn crops to sustain them through the winter. Acorns are also important to ruffed grouse, wild turkey, black bear, gray squirrel, and mice, which use the ROW. Several songbird species using the ROW eat acorns as an important part of their diet. These include yellow-shafted flicker, goldfinch, blue jay, brown thrasher, and rufous-sided towhee. Deer browsed upon bear oak twigs in all seasons on the ROW.

Blackberry—Blackberry fruit was produced in abundance on the ROW (Figure 14) and is a prime summer food for many wildlife species (Martin et al., 1951). The common game birds of the area, ruffed grouse and wild turkey, use the succulent fruit as an important summer food (2 to 5 percent of the diet). White-tailed deer browsed heavily on tender stems and leaves of blackberry in the summer (Figures 15 and 16) and cottontail rabbits browsed stems extensively in both summer and winter. The dense blackberry patches offered excellent tall cover throughout the year and were a common nesting site of small birds (Figure 17).

Blueberries and huckleberry—These are of high value to wildlife, particularly for their fruit (Martin et al., 1951). Ruffed grouse use the succulent berries as important summer and early fall foods; and wild turkeys use the fruit, although to a lesser extent. White-tailed deer have been observed eating the fruit and browsing on twigs and leaves of both blueberries and huckleberry. Cottontail rabbits also browsed these plants. The dense patches of blueberries and huckleberry on the ROW offered good low cover for smaller wildlife species and fawns.

Sweetfern—Although sweetfern is reputed to be of limited value to wildlife (Martin et al., 1951), it provided an important winter browse for white-tailed deer on the ROW (Figure 18) (Bramble and Byrnes, 1972). The utilization value for sweetfern was the highest of all woody plants with a 27 percent density and average browsing of 60 percent (Table 5). Sweetfern is also used by ruffed grouse (1/2-2 percent of the diet).

At peak development, large patches of sweetfern were 3 to 5 feet tall and provided excellent cover for deer and other wildlife species. Game trails and deer beds were common in sweetfern patches.

Teaberry—The large red berries of teaberry which persist over winter in groups of 2 or 3 per plant are used as food by ruffed grouse (2-5 percent of the diet) and wild turkey (1/2-2 percent of the diet) (Martin et al., 1951). Black bear and white-footed mice also use the berries in small quantities. White-tailed deer browse heavily on the entire plant throughout the year.

Witch-hazel—The small, shiny-black seeds of witch-hazel, which are available from fall into winter, are used by ruffed grouse (2-5 percent of the diet) and wild turkey (1/2-2 percent of the diet) (Figure 19). Twigs and foliage were browsed so heavily by deer that witch-hazel edges on the ROW used as cover by deer often showed a marked "deer browse line," bare of branches up to about 5 feet. Cottontail rabbits also feed on the bark and foliage and squirrels use the seeds. The dense, bushy growth of witch-hazel on the ROW provided excellent cover for songbirds, and the edges were observed to be used by deer as resting cover.

Herbaceous Plants as Wildlife Food and Cover

Herbaceous plants on the ROW were important contributors to wildlife food and cover, mostly in the spring, summer, and fall. Although their availability was limited during the winter months, occasional use was made of plants which projected above the usual snow cover, and in open winters some use was made of plants with green basal leaves. Particularly important was the use of herbaceous plants on the ROW in the spring after a snowy winter when the ROW was free of snow in early April when it was still deep in the adjoining forest.

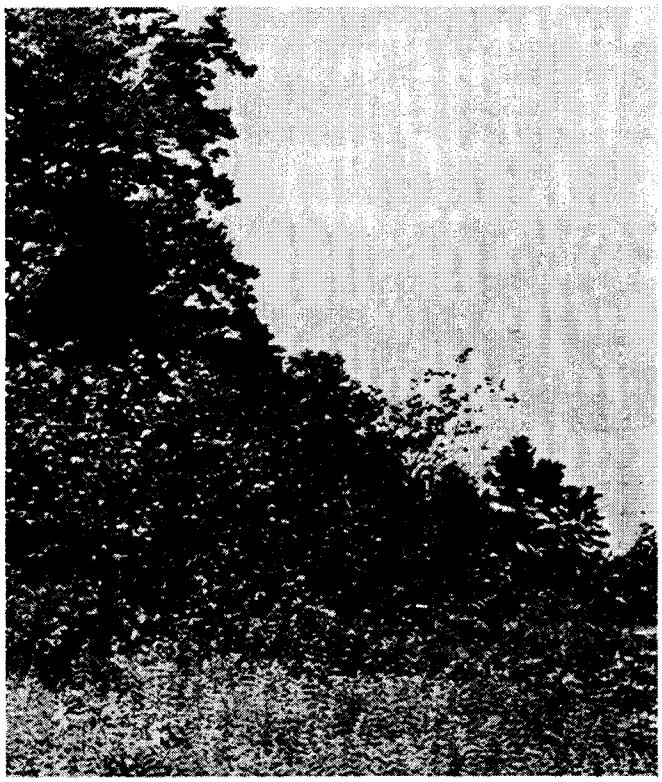

Figure 12. A dense edge of witch-hazel (II D) with a large patch of hayscented fern.

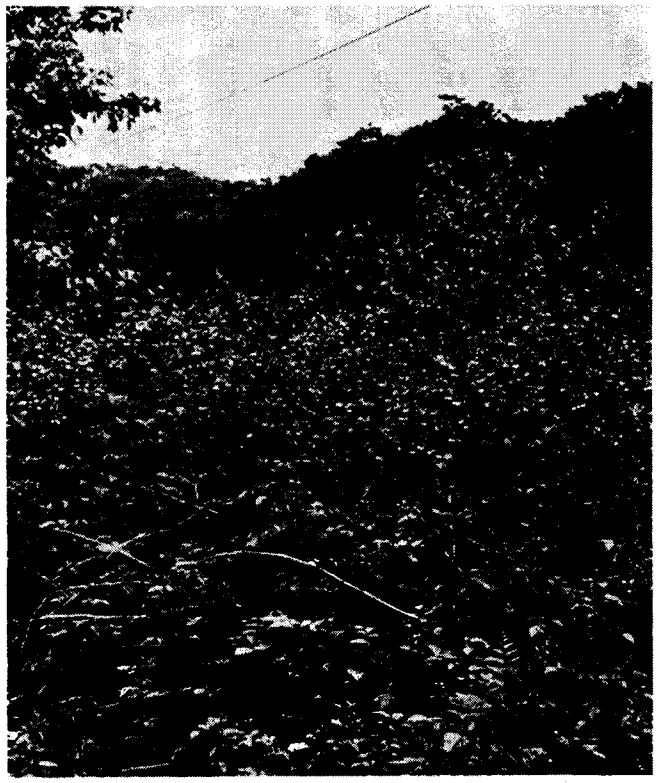

Figure 14. Blackberry in flower provided abundant fruit and dense cover (II F).

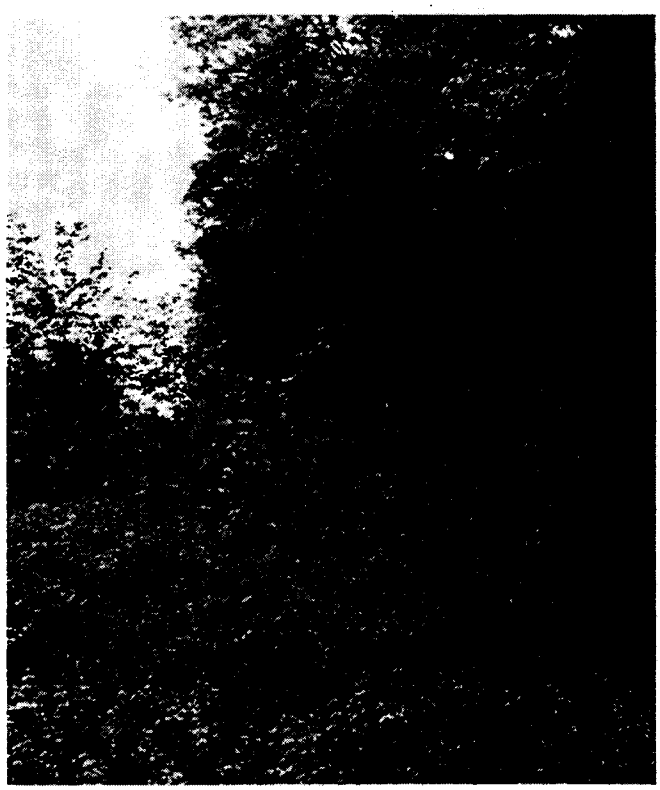

Figure 15. White-tailed deer browsing on the ROW edge (II C). It ate bracken fronds and blackberry stems and leaves.

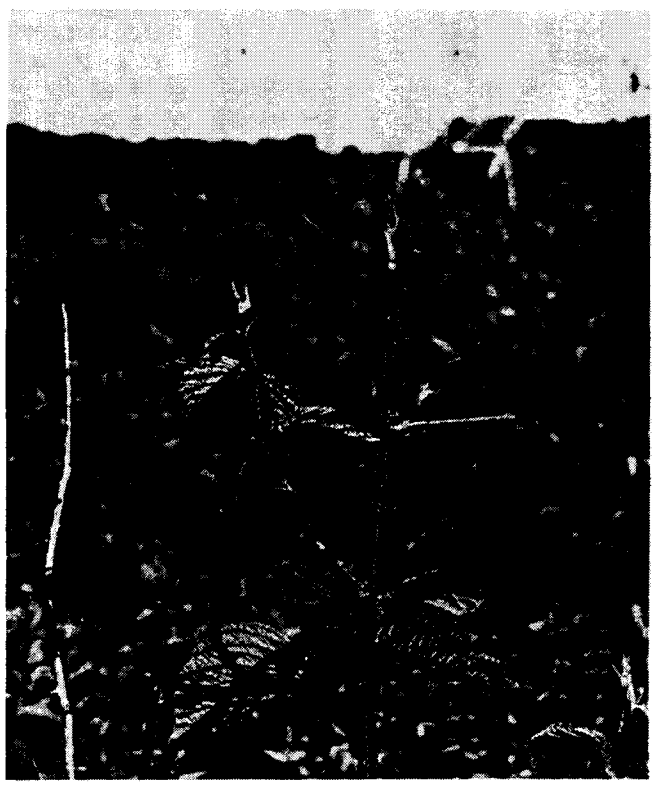

Figure 16. Blackberry stems and leaves browsed by deer in July, 1980 (II D).

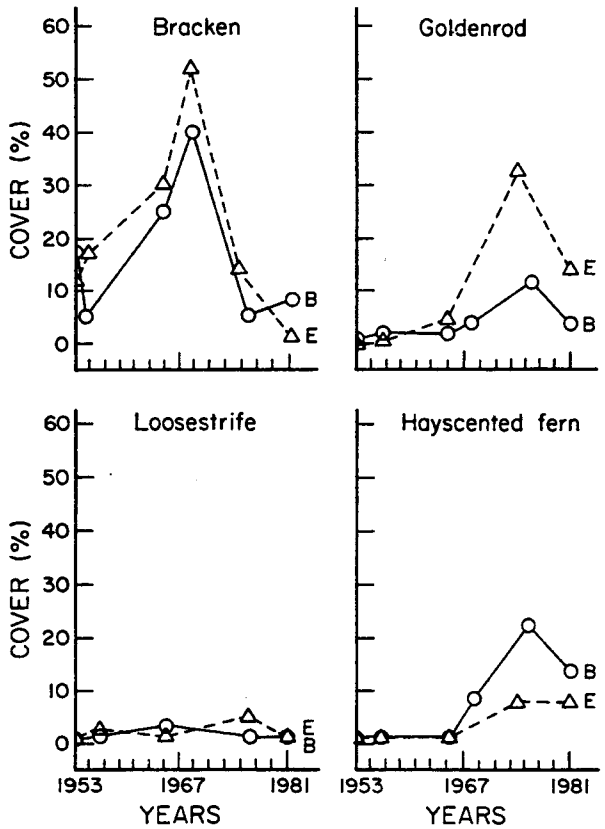

Figure 13. Examples of long-term developmental patterns of herbaceous plants of broadcast D + T (Treatment B) areas and summer basal (Treatment E) areas which had been followed by selective maintenance. Cover percent is the average of four replications. Haysented fern was highly eruptive, goldenrod gradually increased, bracken was eruptive and then gradually decreased, and loosestrife was consistently low in cover values.

Wildlife utilization of common herbaceous species

Bracken—The most important use of this fern was made in the early spring and summer when young fronds were eaten by deer. Bracken received the highest deer utilization rating among herbaceous plants (Table 5). It also is utilized by ruffed grouse in the fall (Kuhn, 1941). Young fronds of bracken were high in protein and minerals as compared to other plants on the ROW and to a synthetic deer ration used in feeding studies (Table 6).

Goldenrods—These tall coarse herbs are used sparingly by wildlife for food (Martin et al., 1951). However, the leaves and stems are eaten by ruffed grouse, cottontail rabbit, and deer (½ to 2 percent of their diet). On the ROW, goldenrods were rated second among herbs as browse during the summer months (Table 5). Goldenrod leaves produced an acceptable feed value rating when compared with a synthetic deer ration (Table 6). Seeds of goldenrods are eaten by the American goldfinch and tree sparrow and meadow mice (Martin et al., 1951). Patches of tall goldenrod on the ROW were excellent cover for wildlife and even young deer were concealed when feeding in such patches.

Whorled loosestrife—Deer browsed loosestrife frequently on the ROW where its low density combined with relatively high browsing gave the species a utilization factor just below bracken and goldenrod (Table 5). It has also been reported as used by cottontail rabbit (Bramble and Byrnes, 1955).

Sheep sorrel—Both the seeds and leaves of this species are eaten by wildlife (Martin et al., 1951), including important game birds such as ruffed grouse and wild turkey. Sheep sorrel has been found to be among the top fall foods of ruffed grouse in central Pennsylvania (Kuhn, 1941). The small seeds are eaten by songbirds such as field sparrow and song sparrow and the leaves and stems by cottontail rabbit. In feed value, sheep sorrel rated well in comparison with a synthetic deer ration used in feeding studies (Table 6).

Panic grasses—These tufted grasses are reported as one of the most important sources of food for ground-feeding songbirds and game birds (Martin et al., 1951). The large ovoid seeds produced in panicles at the ends of branchlets are a favorite food of young wild turkeys, towhee, and various sparrows found on the ROW. The entire plants are eaten by white-tailed deer.

Vernal sedge—Seeds of sedge have been reported as a valuable food for young ruffed grouse and wild turkey and for seed-eating birds such as song sparrow and towhee, all common on the ROW (Martin et al., 1951). Sedge plants are eaten by deer in the spring and winter (Bramble and Byrnes, 1955).

The frequent use of patches of grass as bedding spots for deer is of special interest in use of herbaceous plants as wildlife cover. Tall meadow fescue and poverty grass patches were favored as a location for beds on the ROW. A particularly common location for deer beds was where a grass layer grew under sweetfern.

Discussion

Anton Kerner in his classic forerunner of plant ecology, "The Plant Life of the Danube Basin" wrote, "As within mankind, plant life has its epochs and its history to reveal, and in both we see an eternal wrestle and combat, an eternal destruction and renewal, an everlasting coming and going" (Conard, 1951). Development of vegetation on a ROW is a concrete example of this sort of continuing struggle of plants against each other and the environment that results in a typical plant community. The plant cover on any bounded area of the ROW studied was dynamic in its changes in species composition

and in a continued shifting of dominance. Areas that remained absolutely stable on the ROW over the 30 years were rare indeed. Krebs (1972) has also pointed out that most "stable" communities are actually not stable for long periods because of short-term changes in climate, or other environmental factors, and cyclic changes of growth and decay of dominant species within the community. A stable community, he points out, may be in fact a mosaic of cyclic changes operating at a local level. This appears to be what has happened over 30 years on the ROW in central Pennsylvania and which will probably continue into the indefinite future.

Although plant succession towards the former oak forest has been arrested on the ROW through selective removal of target trees, the lesser vegetation composed of shrubs, herbs, ferns, and grasses has been constantly trending towards development of a dominant shrub cover. Where the more drastic broadcast spray techniques were used, the initial plant cover consisted of sedge, herbs, and grasses as dominant species. This community gradually gave way to a shrub-dominated community under subsequent selective maintenance.

Of considerable ecological interest and important to understanding ROW plant cover development is the fact that most of the dominant plants are perennials which have the ability to spread underground by means of rhizomes or by rhizomatous roots (Figures 7 and 8). Rhizomes are underground stems that produce both stems and roots at their joints, or nodes, so that one plant may spread rapidly to form a patch and invade other established plant groups. This gives species with rhizomes an obvious advantage over plants that must spread by means of seeds. Dominant plants on the ROW that spread by rhizomes, or by adventitious buds from shallow roots, include the shrubs sweetfern, blueberry, teaberry, and blackberry; and the herbaceous species bracken, goldenrod, hayscented fern, sheep sorrel, meadow fescue, vernal sedge, panic grass, and wild sarsaparilla. Very few annual herbs persisted on the ROW and those that did such as cow-wheat were sparse and grew singly. Polycormy, or spread by rhizomes, has been given considerable emphasis in plant sociology and has a practical application in sodding and soil stabilization (Braun-Blanquet, 1964). The term "Polykormie" has been used in Europe to refer to clonal expansion by rhizomes; different forms of root development in weed communities has been

Table 5. Utilization of plants by deer on the sprayed and hand cut right-of-way and in the forest as expressed by a utilization factor (average density x average browsing).

	Sprayed right-of-way			Cut right-of-way			Uncut forest		
	Average density %	Average browsing %	Utilization factor	Average density %	Average browsing %	Utilization factor	Average density %	Average browsing %	Utilization factor
Herbaceous Plants									
Bracken	39	44	1716	18	50	900	18	7	126
Goldenrod	11	57	627	3	70	210	0	0	0
Loosestrife	4	38	152	3	3	9	3	6	18
Aster	4	9	36	0	0	0	0	0	0
Cow Wheat	1	11	11	5	35	175	1	0	0
Sarsaparilla	2	12	24	0	0	0	8	5	40
Woody Plants									
Sweetfern	27	60	1620	18	70	1260	1	56	56
Bear Oak	4	53	212	5	70	350	3	24	72
Blueberry	9	10	90	50	5	250	18	6	108
Blackberry	4	47	188	3	35	105	0	0	0
Sassafras	4	61	244	5	70	350	11	51	561
Witch-hazel	3	52	156	5	50	250	5	40	200
Red Maple	2	37	74	18	70	1260	5	51	255
White Oak	3	53	159	15	35	525	2	38	76
Black Cherry	1	38	38	0	0	0	0	0	0
Chestnut Oak	1	57	57	3	70	210	3	48	144
Red Oak	1	70	70	5	35	175	3	30	90
Laurel	1	70	70	0	0	0	1	43	43

Table 6. Feed value of species commonly eaten by deer on the right-of-way compared with a complete, synthetic deer ration.

Species	Plant part	Protein %	Fat %	Fiber %	Ca %	P %	Mg %	K %	Total minerals
Synthetic deer ration	——	14.4	1.70	14.7	1.27	0.18	——	——	——
Herbs:									
Bracken	Young fronds	37.7	0.92	10.4	0.12	0.30	0.92	3.00	4.34
Goldenrod									
S. graminifolia	Leaves	11.6	1.80	30.2	0.40	0.29	0.09	2.40	3.18
S. rugosa	Leaves	14.0	4.20	19.9	0.74	0.29	0.17	2.60	3.80
Loosestrife	Leaves	15.3	7.50	17.2	0.41	0.26	0.16	2.20	3.03
Sorrel	Leaves	20.4	2.68	18.4	0.37	0.28	0.24	1.99	2.88
Woody Plants:									
Sweetfern	Stems	9.2	3.80	20.9	0.93	0.11	0.11	0.30	1.45
Blueberry									
V. vacillans	Leaves	7.9	3.45	14.4	0.82	0.09	0.17	0.59	1.67
	Stems	4.4	3.70	37.3	0.67	0.10	0.09	0.46	0.96
V. angustifolium	Leaves	9.2	4.95	11.4	0.97	0.08	0.14	0.49	1.68
	Stems	5.3	4.00	38.7	0.52	0.08	0.05	0.31	0.96
Teaberry	Leaves	7.5	3.60	21.8	0.92	0.08	0.19	0.67	1.86
Bear Oak	Stems	5.2	2.90	39.1	——	——	——	——	2.20
Red Maple	Stems	5.7	3.70	37.0	——	——	——	——	2.40

described in a crop atlas of central Europe (Kutschera, 1960).

Implications for ROW Management

One of the major requirements for properly conducted research is that it should enable a prediction of events that will occur as a result of a specific course of action. ROW research, therefore, should provide a manager with information that will enable him to make knowledgeable predictions of future nontarget plant cover development as a result of a certain kind of ROW maintenance.

The present study of a ROW in an oak forest in central Pennsylvania aims to provide such information bearing on ROW management in that extensive forest type and some general principles of vegetation development that can be applied elsewhere in the deciduous forest of the eastern United States. The latter must be done, however, with an understanding of the important variables that affect vegetation on ROWs and must be applied with due care and comprehension of the limits of prediction. For example, trends in vegetation development can be predicted but with the understanding that rates of change will vary in different forest regions and habitats.

What are some of the predictions that can be made?

First, when a ROW is cleared it can be expected that there will be a short-term decrease in total shrub and herbaceous cover owing to mechanical disturbance of vegetation and soil. Species of the forest that can tolerate open conditions will then spread to dominate the ROW plant cover. Other species whose seeds have been stored in the forest floor may also appear shortly after clearance. Blackberry is an example of such species, and, when a seed bank has been built up in the forest litter, it may suddenly produce a dominant cover. However, where only a few seeds are present, as in the area studied, blackberry will first appear sparsely and develop slowly into a dominant species. An important general fact to take into account is that some species which may occur only sparsely after clearance are capable of considerable increase over a period of years. Sweetfern and goldenrods are examples of such species. It is also important to be aware that certain valuable species may be seriously damaged by a certain type of treatment. For example, blueberries are seriously damaged by broadcast sprays while their development is favored by selective sprays. Conversely, blackberry and sweetfern development is favored by the disturbance of a broadcast spray.

After a ROW has been subjected to repeated maintenance applications, plants of the forest and those

Figure 17. Towhee nest with young in a blackberry patch (IE).

Figure 18. Sweetfern browsed by deer in the winter only.

Figure 19. Witch-hazel with abundant fruit (II D).

Figure 20. Shrubby borders of witch-hazel and a low cover of blackberry, blueberry, sweetfern, bracken, sedge, loosestrife, goldenrod, wild sarsaparilla, hayscented fern and grass in 1972 (II F).

Table 7. Maintenance planning and operations carried out on a 3-mile segment of the 230 kV Shawville to Lewistown line which traversed Pennsylvania Gamelands 33.

Objectives:

1. To maintain control of tall-growing woody plants (woody brush)
2. To develop favorable wildlife food and cover

Maintenance:

1951-52	Capital clearance was carried out by clear-cutting with slash piled and burned. The forest type was an oak-red maple mixture with witch-hazel and blueberry common in the understory.
1953-54	Target plant density was medium to high with 1500 to 6000 stems/A, 3-5 ft. height. The ROW was sprayed to control brush and to develop wildlife food and cover. A combination of selective basal and broadcast sprays using 2,4-D, 2,4,5-T, and AMS were used, experimentally.
1955	Target plants had been reduced to less than 200 stems/A, over 3 ft. height.
1958	Field examination was made after 5 years and a report prepared. No maintenance was needed at this time. Light density of target plants of less than 400 stems/A, 3-10 ft. height was present. A dense cover of bracken, sedge, herb, blueberry with some witch-hazel and bear oak edges had developed to serve as wildlife food and cover.
1958-65	Field examinations were made annually during this period. No maintenance was needed. Trees were slowly increasing in number and height which was still under 10' owing to competition from dense nontarget vegetation.
1966	Target plant density was medium with 1260 stems/A, 3-14 ft. height. Plants of openings were being added to nontarget vegetation, mostly sweetfern and goldenrod. A selective basal spray was applied, plus cut stump to large red maple, and stem-foliage to sassafras thickets where needed using 2,4-D + 2,4,5-T.
1966-80	Annual field examinations were made. In 1973, there were 500 stems/A, 3-10 ft. height. Blackberry had increased to become a dominant shrub. Wildlife food and cover were excellent with shrubby patches and edges. Spot cutting and stump spray maintenance was carried out in 1978-1979 to control the tallest trees.
1980	Target plants had increased to 1800 stems/A, 3 to 14 ft. height. ROW was sprayed with a selective basal of dicamba (Banvel 520) in oil in the fall on 1/4 of the segment. The remainder is to be sprayed in 1982. Wildlife food and cover were excellent; shrubs dominated the non-target vegetation. Shrubby edges have increased.

typical of openings will develop into a complex mixture of codominants to form a proclimax vegetation (Figure 20). Although these will be mostly species that can spread vegetatively such as blueberry, bracken, blackberry and goldenrods; species which produce abundant seed crops at strategic times, such as witch-hazel which produces seeds in the fall, can also become dominants on a ROW.

Prominent among the tall-growing tree species (target species) that can be expected to occur commonly on ROWs are those that commonly invade open areas. These are species that produce abundant seed crops which are wind disseminated for considerable distances (red maple, ash, and aspen), are carried by birds (cherry and sassafras), or transported by squirrels (red oak).

On older ROWs, a mixture of forest plants with plants of openings will have developed over time to form a proclimax type of plant community. This community can be maintained by repeated herbicide applications and will be subject to cyclic variations caused by periodic changes in climatic and biotic conditions, such as precipitation and animal browsing. This means that operational management planning should be for relatively short periods such as 5 to 10 years. At the end of each management period the planning should be revised to take into account what has occurred and what changes appear probable in the near future. Such short-term planning can be done within the framework of a long-term plan which sets forth the important general objectives of management.

An example of a management plan applied to the research segment under study is shown in Table 7. The major long term objectives were: (1) to control tall-growing trees and shrubs which could interfere with electric transmission, and (2) to develop desirable wildlife food and cover. Following the original set of research treatments, selective herbicide treatments were considered best suited to meet management objectives.

Appendix

Common and Scientific Names of Plants Referred to in the Report

Arbutus, trailing	*Epigaea repens*
Ash, white	*Fraxinus americana*
Aspen	*Populus* spp.
Azalea	*Rhododendron nudiflorum*
Blackberry	*Rubus allegheniensis*
Blueberry	*Vaccinium angustifolium*
	Vaccinium vacillans
Bracken	*Pteridium aquilinum*
Carrion flower	*Smilax herbacea*
Cherry, black	*Prunus serotina*
pin	*Prunus pennsylvanica*
Chokeberry, black	*Pyrus melanocarpa*
red	*Pyrus arbutifolia*
Cinquefoil	*Potentilla* spp.
Cow-wheat	*Melampyrum lineare*
Deerberry	*Vaccinium stamineum*
Dewberry	*Rubus hispidus*
Dogwood, flowering	*Cornus florida*
Fern, hayscented	*Dennstaedtia punctilobula*
Fescue, meadow	*Festuca elatior*
Fireweed	*Erechtites hieracifolia*
Goldenrod	*Solidago graminifolia*
	Solidago rugosa
Gooseberry	*Ribes* spp.
Grape	*Vitis* spp.
Hawthorn	*Crataegus* spp.
Hazelnut	*Corylus americana*
Hickory	*Carya* spp.
Holly, deciduous	*Ilex verticilata*
mountain	*Ilex montana*
Honeysuckle, bush	*Diervilla lonicera*
Huckleberry	*Gaylussacia baccata*
Indian cucumber root	*Medeola virginiana*
Lady's slipper	*Cypripedium acaule*
Lilly, woods	*Lilium philadelphicum*
Loosestrife	*Lysimachia quadrifolia*
Maple, red	*Acer rubrum*
Mountain laurel	*Kalmia latifolia*
Oak, bear	*Quercus ilicifolia*
black	*Quercus velutina*
chestnut	*Quercus montana*
red	*Quercus rubra*
white	*Quercus alba*
Panic grass	*Panicum commutatum*
	Panicum latifolium
Poverty grass	*Danthonia spicata*
Sassafras	*Sassafras albidum*
Sawbrier	*Smilax glauca*
Sedge, vernal	*Carex pensylvanica*
Serviceberry	*Amelanchier* spp.
Sorrel, sheep	*Rumex Acetosella*
Solomon's seal, false	*Smilicina racemosa*
Sweetfern	*Comptonia peregrina*
Teaberry	*Gaultheria procumbens*
Upland rice grass	*Oryzopsis asperifolia*
Viburnum, dentate	*Viburnum dentatum*
maple-leaved	*Viburnum acerifolium*
Wild sarsaparilla	*Aralia nudicaulis*
Witch-hazel	*Hamamelis virginiana*

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