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We are submitting herewith a thesis written by Brian N. Clark entitled "Effects of Tebuthiuron on Wildlife Habitat on Two Powerline Rights-of-way and Public Perception of Powerline Right-of-way Management in Eastern Tennessee." We have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree Master of Science, with a major in Wildlife and Fisheries Science.

David A. Buehler, Major Professor

J. Mark Fly, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor
and Dean of the Graduate School

EFFECTS OF TEBUTHIURON ON WILDLIFE HABITAT ON TWO POWERLINE RIGHTS-OF-WAY AND PUBLIC PERCEPTION OF POWERLINE RIGHT-OF-WAY MANAGEMENT IN EASTERN TENNESSEE

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[1]TVA sponsorship of this project is not to be deemed a warranty of any procedures, materials, and/or apparatus identified herein for any purpose and further, any such reference to TVA is not to be construed as an endorsement of any such procedures, materials, and/or apparatus or source thereof.

ABSTRACT

I measured woody and herbaceous vegetation in fall before (1992) and for 2 years after (1993-1994) tebuthiuron treatment (6.8 kg active ingredient/ha) on 2 electric transmission-line rights-of-way (ROWs) on the University of Tennessee Oak Ridge Forest. I used vegetation measures to evaluate tebuthiuron-induced habitat changes for several wildlife species. I also held focus groups on ROW management with eastern Tennessee residents. I interviewed participants about their perceptions of different vegetative cover types on ROWs, chemical and mechanical treatment types, and wildlife habitat.

Vegetation changes were similar across ROWs following tebuthiuron treatment. Tree density decreased ($P \leq 0.001$) 84-95% 2 years following treatment. Shrub density decreased ($P \leq 0.05$) 55-59% 2 years following treatment. Vine density increased 17-36% 2 years post-treatment ($P \leq 0.05$). Grass and sedge density increased 477-790% from 1992 to 1994 ($P < 0.001$). Forb density increased 115-167% during the study ($P < 0.004$); fern density increased 475% on 1 ROW 1992-1994 ($P = 0.022$).

Eight of the 10 most dominant tree and shrub species decreased in frequency of occurrence across plots after treatment ($P < 0.001$). Frequency of occurrence across plots for the 8 most dominant herbaceous plant and vine species did not differ 2 years after treatment ($P < 0.001$). Species richness of trees and shrubs decreased ($P < 0.001$) from 5-6 species/plot, on average, in 1992 to 1-2 species/plot, on

average, in 1994. Species richness of grasses, sedges, forbs, ferns, and vines increased ($P < 0.001$) across plots from 5-6 species/plot in 1992 to 8-11 species/plot in 1994.

Maximum tree and shrub height on plots decreased ($P < 0.001$) from 2-5 m pretreatment to 1-2 m 2-years post-treatment. Estimated heights for many of the most dominant tree and shrub species decreased ($P < 0.001$) following tebuthiuron treatment. Vertical cover decreased ($P < 0.001$) 55-75% 1 year following treatment, but only differed (25% decrease) on 1 ROW after 2 years ($P = 0.006$).

Total ground cover by low-growing plants increased from 63-72% before treatment to 120-130% 2 years after treatment ($P < 0.001$). Coverage by grasses and sedges, and forbs increased ($P < 0.001$) from 286-470% and 239-340%, respectively. Coverage by ferns and vines varied by ROW.

Total plant biomass declined after tebuthiuron treatment. Dry weight of trees decreased 97-99% 2 years after tebuthiuron treatment ($P < 0.001$). Shrub dry weights increased slightly on one ROW after treatment ($P < 0.003$). Vine dry weights decreased 74-86% ($P < 0.001$). Grass and sedge dry weights increased 558-624% ($P < 0.001$). Forb and fern dry weights decreased 29% on one ROW after treatment ($P = 0.023$).

Wildlife habitat improved for species that use openings for food or cover such as white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*), grasshopper sparrow (*Ammodramus savannarum*), and northern bobwhite (*Colinus virginianus*). Increased herbaceous plant density, ground cover, and grass biomass

probably increased forage abundance and availability for eastern cottontails (*Sylvilagus floridanus*), meadow vole (*Microtus pennsylvanicus*), white-footed mouse (*Peromyscus leucopus*), gray fox *(Urocyon cinereoargenteus*), and red-tailed hawk (*Buteo jamaicencis*). Reduction of trees and shrubs probably decreased the ROWs' food and cover value to práirie warbler (*Dendroica discolor*), wood thrush (*Hylocichla mustelina*), ruffed grouse (*Bonasa umbellus*), and other species that require woody stems for food or cover. Vegetation changes on ROWs following tebuthiuron treatment diversified the Oak Ridge Forest and provided herbaceous cover largely unavailable on the Forest before treatment.

A majority of focus group participants preferred mechanical cutting over herbicide use for ROW management, though several expressed approval of herbicides if chemicals used were proven safe and effective. Participants wanted detailed information about any herbicide being considered for use on large areas like ROWs. Tebuthiuron was unfamiliar to most respondents; a description of the chemical was received by many with the same skepticism about safety, effectiveness, and cost shown toward other pesticides. Landowners identified contact by the utility prior to ROW treatment as the most important ROW management consideration.

Most participants were skeptical of federal pesticide regulation, and they trusted few sources of information on herbicides. Data from popular media, chemical companies, and government agencies were believed to be biased because of financial or other motivations. Participants placed more trust in university and independent research data.

Most focus group participants preferred grass or shrub cover to tall brush cover on ROWs for aesthetic, safety, or utilitarian reasons. ROWs were perceived as wildlife habitat by very few. Most participants thought of habitat as "parks," "forests" and "natural areas"--areas without human intervention or management.

Results indicated that ROWs can be managed to benefit people and wildlife. Managers should: (1) solicit input from landowners and other groups to improve public relations and understand public perceptions; (2) provide detailed information about ROW treatments and the importance of wildlife management on private lands; and (3) promote grass or shrub cover to maximize ROW benefits.

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PART 1: GENERAL INTRODUCTION

CHAPTER 1

THE IMPORTANCE OF RIGHT-OF-WAY MANAGEMENT

One of the greatest challenges facing humankind is that of integrating environmental stewardship with technological progress. Research that helps resolve conflicts between conservation and technology is greatly needed (Hunter 1990). The electric power industry has received much attention in this regard because of electromagnetic fields (Bankoske et al. 1976), air and water effluent regulation (Noll et al. 1975, Saila 1975), power generation and delivery facility siting and construction (Jackson et al. 1978, Cupit 1981, Howlett 1984, Simutis and Johnson 1984), and rights-of-way (ROWs) management (Tillman 1976, Tillman 1979, Crabtree 1982, Byrnes and Holt 1987)

Utility ROW maintenance is of importance to wildlife resource managers (Egler 1957). Land area encompassed in ROWs in the United States is substantial; in 1970 an estimated 1.6 million ha were occupied by electric transmission ROWs alone (U.S. Dep. Agric. and U.S. Dep. Inter. 1970, Egler and Foote 1975). These corridors influence wildlife distribution, abundance, and population dynamics (Schreiber et al. 1976, Anderson et al. 1977, Johnson et al. 1979, Morgan and Gates 1982, Doucet et al. 1987, Gates 1991).

Linear features such as powerline ROWs diversify habitats through edge and interspersion effects. The impacts of those effects depend on the wildlife species and

landscapes involved (Wegner and Merriam 1979, Morgan and Gates 1983, Forman 1987). ROWs may provide important habitat features for some species. Habitat in ROWs that contrasts with adjacent areas benefit wildlife that utilize differing food and cover types seasonally or during different life stages. Wild turkeys, for example, require herbaceous cover and abundant insects during spring and summer for poult-rearing, but turkeys rely heavily on mature oak (*Quercus* spp.) stands for hard mast during fall and winter (Sanderson and Schultz 1973, Everett et al. 1981, Hamel 1992). White-tailed deer also benefit from the juxtaposition of different habitat types, such as those created by the location of ROWs adjacent to agricultural lands, forests, or wetlands (Short 1986, Kennedy et al. 1991).

Raptors use maintained, open areas such as utility corridors because perch sites are readily available and because prey may be more easily detected (Baker and Brooks 1981, Mersmann and Fraser 1990). Canids use ROWs for travel and for foraging because of increased prey concentrations along corridor edges (Gates 1991). ROWs may also improve some songbirds' habitat. The prairie warbler, a neotropical migratory songbird considered a management priority species in the Southeast (W. C. Hunter, U.S. Fish Wildl. Serv., pers. commun.), utilizes open lands with brushy cover, such as conditions found in many utility corridors (Hamel 1992). Prairie warbler distribution and abundance may be restricted in the East by the lack of land area maintained in sapling-shrub cover (Robbins et al. 1989). Depending on other landscape-scale habitat conditions, ROWs could be important for supporting wildlife

species such as the prairie warbler that require relatively low-growing seral stages (Kroodsma 1984, Robbins et al. 1989).

Some wildlife do not benefit from the location of utility corridors in landscapes otherwise devoid of large-scale human disturbance. Some wildlife species are area-sensitive, requiring large, contiguous forest blocks for successful reproduction and foraging (Robbins et al. 1989, Askins et al. 1990). Some songbirds are also particularly susceptible to nest parasitism by brown-headed cowbirds (*Molothrus ater*) or predation because of habitat fragmentation induced by development and corridor establishment (Chasko and Gates 1982, Wilcove 1985, Small and Hunter 1988). Utility corridors also have been shown to limit the movements of some wildlife; cover that starkly contrasts surrounding habitat can inhibit or discourage wildlife use and impede travel (Wegner and Merriam 1979, Forman 1987, Gates 1991). Identification of key habitat requirements and evaluation of habitat management techniques available for mitigating such ROW effects may be critical for conserving wildlife in the future (Hoover and Galvin 1981).

Manual and mechanical cutting, and herbicide applications have been the principal vegetation management methods employed by electric transmission ROW managers responsible for maintaining line clearance and access to facilities (Bramble and Byrnes 1955, Galvin et al. 1979). Numerous studies have identified benefits and drawbacks of ROW management alternatives, including cutting, burning, seeding, broadcast and selective herbicide treatments, plant growth regulators, and nitrogen application (Bramble and Byrnes 1974, Egler and Foote 1975, Arner et al. 1976,

Beeman and Schreiber 1976, Chappell et al. 1976, Fowler et al.1976, Woodhouse and Baynes 1976, Ulrich 1976, Huntley and Arner 1981, Johnston 1984, Hanson 1988, Harlow 1991). Cutting achieves line clearance, can be inexpensive, and can be selective, but cutting must be frequently repeated and increases tree stem densities (Egler and Foote 1975, Ulrich 1976, Harlow 1991). Herbicides and growth regulators can produce low maintenance, high quality ROW habitat, but initial costs can be high, the potential for environmental contamination exists, and public perceptions can be problematic (Bramble and Byrnes 1974, Egler and Foote 1975, Arner et al. 1976, Chappell et al. 1976, Hanson 1988). Burning can eliminate woody plants and enhance herbaceous productivity, but it can be difficult to administer and it can leave soil open to erosion (Arner et al. 1976, Harlow 1991). Propagation of legumes or other desirable wildlife foods through seeding and fertilizing can improve ROW habitats for some species, but the treatments can also increase ROW management costs and may provide only temporary benefits (Arner et al. 1976, Woodhouse and Baynes 1976, Harlow 1991).

Public perception complicates the ROW management process (Egler and Foote 1975, Jackson 1981, Marquis 1987). Contact with landowners or public agencies is necessary because ROWs usually involve easements. The acquisition and upkeep of land and vegetation on ROWs is of interest to property holders because of development limitations, treatment effects, and aesthetics (Feher 1987, Priestley 1992, Clark et al. 1995). These factors encourage ROW managers to implement programs

that are not only feasible in terms of controlling plant growth, but are also favorably perceived by affected publics.

Herbicides that control trees, promote herbaceous vegetation and are environmentally safe are in high demand (Egler and Foote 1975, Defazio 1986). Tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea) has been researched for ROW and forest management application because of its mode of action, effectiveness, and moderate toxicity (Christenson et al. 1974, Peevy 1975, Chang and Stritzke 1977, Bovey et al. 1978, Hatzois et al. 1980, McNeil et al. 1980). Registered for use in 1979, this herbicide's effects on vegetation and wildlife habitat have been documented in the West, Southwest, and Southeast on a limited number of vegetation types (Worsham et al. 1974, Scifres and Mutz 1978, Meyer and Bovey 1980, Doerr and Guthery 1983, Defazio 1986, Stone 1986, Fulbright and Garza 1991). Tebuthiuron effectively controlled problematic woody species and tended to produce abundant grasses in these settings. However, no research has addressed the use of tebuthiuron for vegetation management in the Ridge and Valley physiographic province. More site-specific studies are necessary to quantify the chemical's potential for ROW and forest management under different soil, climatic, and topographic conditions (Defazio et al. 1988*a*, Robinson and Bolen 1989).

Few published attitudinal data document public sentiment about vegetation management and herbicide use on ROWs. Such information is needed in natural resource management for determining program objectives, identifying information and education needs, and evaluating programs (Slovic 1990, Cruikshank 1992, Priestley

1992, Clark et al. 1994). Public perception of land aesthetics and vegetation management activities can significantly influence the effectiveness of programs and organizations involved in land and natural resource management (Patey and Evans 1979, Morris 1987, Powell 1987, Cruikshank 1992, Clark et al. 1995).

This thesis presents a 2-fold investigation relating to ROW management in eastern Tennessee. First, I present an assessment of an inventory of tebuthiuron's (Spike® 40P, DowElanco, Inc., Indianapolis, Ind.) effects on ROW vegetation and wildlife habitat on 2 transmission ROWs in Anderson County, Tennessee. I discuss the composition, structure and dynamics of vegetative communities on the ROWs before and 2 years following tebuthiuron treatment. I also review the implications of tebuthiuron-induced habitat changes for a cross-section of the wildlife community: white-tailed deer, white-footed mouse, meadow vole, eastern cottontail, ruffed grouse, northern bobwhite, wild turkey, gray fox, red-tailed hawk, grasshopper sparrow, prairie warbler, and wood thrush. Second, I report the procedures and results of a study of public perceptions pertaining to powerline corridor management in eastern Tennessee. This study involved focus group interviews with landowners and other publics about vegetation and wildlife habitat management on ROWs, herbicide use, and aesthetic preferences for ROWs. I discuss the public relations aspects of ROW and wildlife habitat management with tebuthiuron and herbicides in general, and possible means of integrating both human and biological concerns into ROW management.

PART 2: EFFECTS OF TEBUTHIURON ON WILDLIFE HABITAT

CHAPTER 2

LITERATURE REVIEW

Properties of Tebuthiuron

Mode of Action and Environmental Fate

Tebuthiuron is a colorless solid with a slightly pungent odor, and it is noncorrosive, nonflammable, and stable in storage (Herbicide Handb. Comm. 1989). It has a water solubility of 0.25 g/mL at 25 C.

Tebuthiuron is soil-applied in pellet, granule, wettable powder, or dry flowable form (Herbicide Handb. Comm. 1989). It dissolves with precipitation, penetrates usually to 70 cm or less, and binds to clay or organic matter in soils (Chang and Stritzke 1977, Duncan and Scifres 1983). The chemical exhibits little lateral movement once bound (Chang and Stritzke 1977).

Tebuthiuron is readily absorbed by plant roots and translocated in plant tissues (Steinert and Stritzke 1977, McNeil et al. 1980). Tebuthiuron appears to inhibit photosynthesis (Hatzois et al. 1980, Ashton and Crafts 1981), and it is metabolized in plants via N-demethylation and hydroxylation of the tertbutyl side chain (Eaton et al. 1976, Magnussen and Rainey 1977). Affected woody plants often display leaf-drop and a number of refoliations before mortality (Pettit 1979). Microbial degradation of tebuthiuron has been demonstrated; losses of the chemical from soil due to photodecomposition and volatilization are said to be negligible (Herbicide Handb.

Comm. 1989). The herbicide's half-life in soil is 12-15 months in areas with 102-152 cm of annual rainfall; areas with substantially less rainfall and or high organic soil content prolong tebuthiuron's activity (Chang and Stritzke 1977).

Toxicity

The general toxicity of tebuthiuron to birds and aquatic organisms is described as "non-hazardous" (Morton and Hoffman 1976, Herbicide Handb. Comm. 1989). The oral median lethal dose (MLD) for mallards (*Anas platyrhynchos*) is >2000 mg/kg. The 5-day median lethal concentration (MLC) in diets of mallards and northern bobwhites (*Colinus virginianus*) is >5000 mg/kg. MLC (96 hours) for bluegill (*Lepomis macrochirus*) is 112 mg/L (Morton and Hoffman 1976, Herbicide Handb. Comm. 1989).

No-observable-effect-levels for 90-day diets of rat (*Rattus norvegicus*) and dog (*Canis familiaris*), respectively, are 100 mg/kg and 25 mg/kg of tebuthiuron (Todd et al. 1974, Morton and Hoffman 1976). No carcinogenic effects have been detected. Spike 40P, the tebuthiuron formulation used at Oak Ridge, has an acute dermal MLD for rabbits (*Oryctolagus cuniculus*) of >2000 mg/kg. This tebuthiuron formulation does not irritate rabbits' skin, although it does induce slight eye irritation. Detailed toxicological information and other formulation-specific data are presented by Todd et al. (1974), Morton and Hoffman (1976), and Herbicide Handbook Committee (1989).

Effects on Vegetation

Tebuthiuron has been tested for industrial sites and other areas for producing bare ground (Christensen et al. 1974, Ford et al. 1974, Lade et al. 1974, Worsham et al. 1974), but most studies focused on improving rangelands, forests, or open areas by removing tree and shrub species and releasing desirable cover and forage plants for wildlife or livestock (Sosebee et al. 1979, Doerr and Guthery 1983). Tebuthiuron typically caused reductions in trees and shrubs, increased in grasses and sedges, and had variable effects on forbs and vines depending on site, species composition, and time elapsed since treatment (Lade et al. 1974, Pettit 1979, Defazio 1986, Jones and Pettit 1984, Scifres and Koerth 1986, Guthery et al. 1987, Thompson et al. 1991).

Trees and Shrubs

Tebuthiuron appeared to reduce woody vegetation at all application rates in most situations where it was tested. Tebuthiuron killed overstory trees and shrubs in eastern deciduous and mixed deciduous-coniferous forests (Peevy 1975, Myers 1984, Defazio 1986, Defazio et al. 1988*a*, Thompson et al. 1991). Oaks, hickories (*Carya* spp.), pines (*Pinus* spp.), sweetgum (*Liquidambar styraciflua*), bayberry (*Myrica heterophylla*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), dogwood (*Cornus florida*), sumac (*Rhus* spp.), wild black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), bicolor lespedeza (*Lespedeza bicolor*), and sparkleberry (*Vaccinium arboreum*) have shown susceptibility to tebuthiuron (Peevy 1975, Myers 1984, Defazio 1986, Defazio et al. 1988*a*, Thompson et al. 1991).

Sassafras (*Sassafras albidum*), however, showed no response or increased in frequency of occurrence after tebuthiuron treatment (Myers 1984, Defazio et al. 1988*a*).

Tebuthiuron also killed a variety of southwestern rangeland tree and shrub species, including sand shinnery oak (*Q. havardii*), blackbrush acacia (*Acacia rigidula*), guajillo (*Acacia berlandieri*), whitebrush (*Aloysia lycioides*), creosotebush (*Larrea tridentata*), twisted acacia (*A. tortuosa*), spiny hackberry (*Celtis pallida*), and wolfberry (*Lycium berlandieri*) (Pettit 1979, Ibarra Flores 1984, Jones and Pettit 1984, Cox et al. 1986, Scifres and Koerth 1986, Scifres et al. 1987). Honey mesquite (*Prosopis glandulosa*), Texas persimmon (*Diospyros texana*), and huisache (*Acacia farnesiana*) showed tolerance of tebuthiuron's effects (Scifres and Koerth 1986). Most research demonstrated high levels of tree and shrub species control with tebuthiuron in the short run (1-4 years), but long-term (5-20 years) monitoring of treated areas is needed for comparing tebuthiuron treatment with other vegetation management options (Scifres 1980, Defazio et al. 1988*a*, Fulbright and Garza 1991).

Vines

Documentation of tebuthiuron's effects on vines is limited. In Georgia mixed pine-hardwood forests, frequencies of occurrence and dry weights of Japanese honeysuckle (*Lonicera japonica*) and Virginia creeper (*Parthenocissus quinquefolia*) decreased on treated vs. control sites (Defazio et al. 1988*a*). In an Oklahoma study, vine biomass was not significantly altered by treatment (Thompson et al. 1991). Because vines are an important wildlife habitat component in some areas (Short 1986,

Defazio 1986), more conclusive results on effects of tebuthiuron on vines in different regions are needed.

Grasses and Sedges

Grasses and sedges tended to increase in density, cover, and biomass after tebuthiuron application (Jones and Pettit 1984, Fulbright and Garza 1991). Poaceae grasses, broomsedge (*Andropogon virginicus*), King Ranch bluestem (*Bothriochloa ischaemum*), pink pappusgrass (*Pappophorum bicolor*), perennial threeawns (*Aristida* spp.), false-rhodesgrass (*Chloris pluriflora*), *Cenchrus* spp., panic grasses (*Panicum* spp.), and Texas bristlegrass (*Setaria texana*) responded positively to tebuthiuron treatment in research in the Southeast and Southwest (Scifres and Mutz 1978, Sosebee et al. 1979, Scifres and Koerth 1986, Guthery et al. 1987, Defazio et al. 1988*a*).

In some cases, grasses were sensitive to tebuthiuron. Worsham et al. (1974) reported near total elimination of saltmeadow cordgrass (*Spartina patens*) and purple top (*Tridens flavus*) after high rates of application on the North Carolina coast. Smooth bromegrass (*Bromus inermis*) and orchardgrass (*Dactylis glomerata*) were nearly eliminated from a railroad bed in Massachusetts (Christenson et al. 1974). Some grasses increased in frequency of occurrence after tebuthiuron applications in Texas, but others were reduced (Pettit 1979). This variation in tebuthiuron phytotoxicity to grasses demonstrates the need for additional, site-specific range and habitat research.

Forbs

Most research on tebuthiuron-plant interactions reported initial decreases in forbs, often followed by recovery (Nickels and Stritzke 1977, Scifres and Mutz 1978, Sosebee et al. 1979, Guthery et al. 1987). Some forbs were affected 1-4 years after tebuthiuron treatment, while other species showed little effect or increased in the absence of intense competition post-treatment (Scifres and Mutz 1978, Scifres and Koerth 1986, Guthery et al. 1987, Defazio et al. 1988*a*). Net increases in forb biomass, ground cover, or frequency of occurrence were observed 1-5 years after application in some cases (Doerr and Guthery 1983, Scifres and Koerth 1986, Fulbright and Garza 1991, Thompson et al. 1991). The interaction of application rate, soil type, rainfall, and species composition appeared to affect the acuteness of forb declines following treatment; higher application rates [>2 kg active ingredient (a.i.)/ha] depressed forbs more substantially and for longer periods regardless of site (Scifres and Mutz 1978, Pettit 1979, Sosebee et al. 1979, Masters and Scifres 1984, Scifres and Koerth 1986, Guthery et al. 1987, Defazio et al. 1988*a*). When trees and shrubs were eliminated, forbs were important for soil stability as well as for wildlife food and cover (Pettit 1979, Thompson et al. 1991). Knowledge of forb response to tebuthiuron in a variety of environmental conditions would provide wildlife managers with more certainty about treatment effects on wildlife habitat for a given management area.

Species Richness

Tebuthiuron effects on plant diversity were dependent on site and species composition. Some treated areas exhibited little variation in richness or community composition after tebuthiuron treatment (Scifres and Mutz 1978). Other study areas showed reductions (Guthery et al. 1987), increases (Doerr and Guthery 1983), or variations by site (Scifres and Koerth 1986). Because plant community richness and composition may influence wildlife use of an area (Hunter 1990), it is important that effects of tebuthiuron on floral diversity be quantified for different habitat types.

Effects on Wildlife and Habitat

The effects of tebuthiuron on wildlife were studied for a variety of species in the South and Southwest, including white-tailed deer, birds, and small mammals. Tebuthiuron was benign or beneficial to deer through its effects on habitat (Defazio 1986, Defazio et al. 1988*a*, Fulbright and Garza 1991, Thompson et al. 1991). On a mixed-hardwood forest in Oklahoma, tebuthiuron temporarily opened the overstory and improved grass production, although desirable forbs may have been suppressed (Thompson et al. 1991). Deer habitat on the Coastal Plain and Piedmont Plateau in Georgia was affected little by site preparation with tebuthiuron; minor decreases in plant frequencies of occurrence and reductions in woody browse biomass were said to be offset by increased grass and forb production (Defazio 1986, Defazio et al. 1988*a*). Live oak reduction on Texas range habitat resulted in grass increases 2-4 years after tebuthiuron application; deer body weights and diets were similar on

tebuthiuron-treated and control areas 3 and 4 years following treatment (Fulbright and Garza 1991).

Tebuthiuron use produced mixed effects for bird habitat (Worsham et al. 1974, Doerr and Guthery 1983, Stone 1986, Guthery et al. 1987, Defazio et al. 1988*b*). Post-treatment increases in bunchgrass (*A. scoparius, A. halii, Sporobulus crypandrus,* and *Eragrostis* spp.) canopy cover and vertical cover improved lesser prairie chicken (*Tympanuchus pallidicinctus*) habitat in Texas (Doerr and Guthery 1983). Lower rates (0.2-0.6 vs. 0.8-1.0 kg a.i./ha) of tebuthiuron produced more seed than control plots, so food availability for prairie chickens was greater following treatment. Abundance and diversity of insects were not significantly affected by the herbicide (Doerr and Guthery 1983). Stone (1986) found significantly greater graminoid seed production but significantly lower invertebrate availability during fall on treated (3.1 kg a.i./ha) versus control sites on Georgia's Piedmont Plateau; granivorous birds may have been aided by the treatment, while insectivores may have suffered from the fewer invertebrates on treated sites. Tebuthiuron removed 98-100% of herbaceous vegetation from dredge islands and thus improved colonial shorebird nesting habitat in coastal North Carolina (Worsham et al. 1974). Tebuthiuron's lack of selectivity on some soils at higher application rates (>1 kg a.i./ha) could prove to be useful for managers of wildlife species such as shorebirds or prairie chickens that require bare ground or sparsely vegetated habitat (Lade et al. 1974, Worsham et al. 1974, Taylor 1979).

No significant differences in abundance of deer mice (*P. leucopus* and *P. maniculatus*), hispid cotton rat (*Sigmodon hispidus*), and oldfield mice (*P. polionotus*)

on treated (2.8-3.1 kg a.i./ha) versus control sites were found in Georgia (Defazio et al. 1988*b*). Tebuthiuron effects on other wildlife species have not been documented. Also, no research focusing on tebuthiuron-wildlife habitat interactions in the Ridge and Valley physiographic province has been conducted. Documentation of the chemical's effects on vegetation and the implications of those effects along the range of environmental gradients in the Southeast is necessary for wildlife managers to fully assess the chemical's value for habitat management.

CHAPTER 3

STUDY AREA

A utility corridor containing 2 parallel electric transmission line ROWs transects the University of Tennessee Forestry Experiment Station's Oak Ridge Forest in Anderson County, Tennessee (Figures 1 and 2). The 2 ROWs were cleared and are maintained by TVA. ROW 1, containing a 161-kV line (Bull Run to Elza) suspended from wooden H-frame structures, was cleared in 1953 and maintained by periodic (3-4-year rotation) mechanical and manual brush-cutting; the last cutting prior to the initiation of this study was in fall 1989. ROW 2 contains 2 161-kV lines (Bull Run to Oak Ridge/Kingston) suspended from steel lattice structures. It was cleared in 1964 and was also maintained by brush-cutting; ROW 2 was last cut in spring 1992. The combined ROWs are 78.8-m wide and are separated by a narrow strip of tall snags--trees killed by hand-applied, 40% a.i. tebuthiuron pellets in 1990. Approximately 1.4 km of the corridor transverses the Oak Ridge Forest.

The Oak Ridge Forest is a 905-ha research and demonstration area that lies in the Ridge and Valley physiographic province in eastern Tennessee, in a broad valley between the Cumberland Plateau and the Unaka Mountains. The parent rock material along the utility corridor is dolomitic limestone and the soil is in the Fullerton cherty silt loam series, taxonomically described as a clayey, kaolinitic, thermic Typic Paleudult soil (Moneymaker 1981).

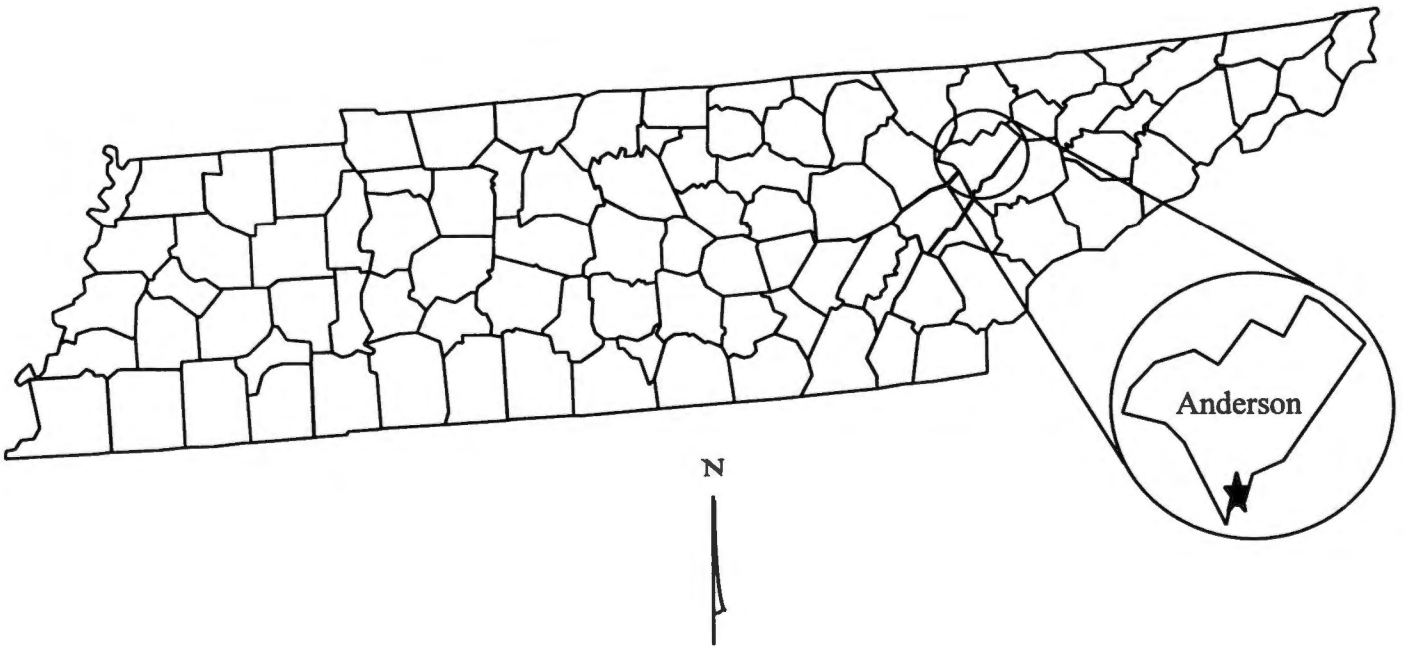


Figure 1. Location of Oak Ridge Forest in Anderson County, Tennessee.

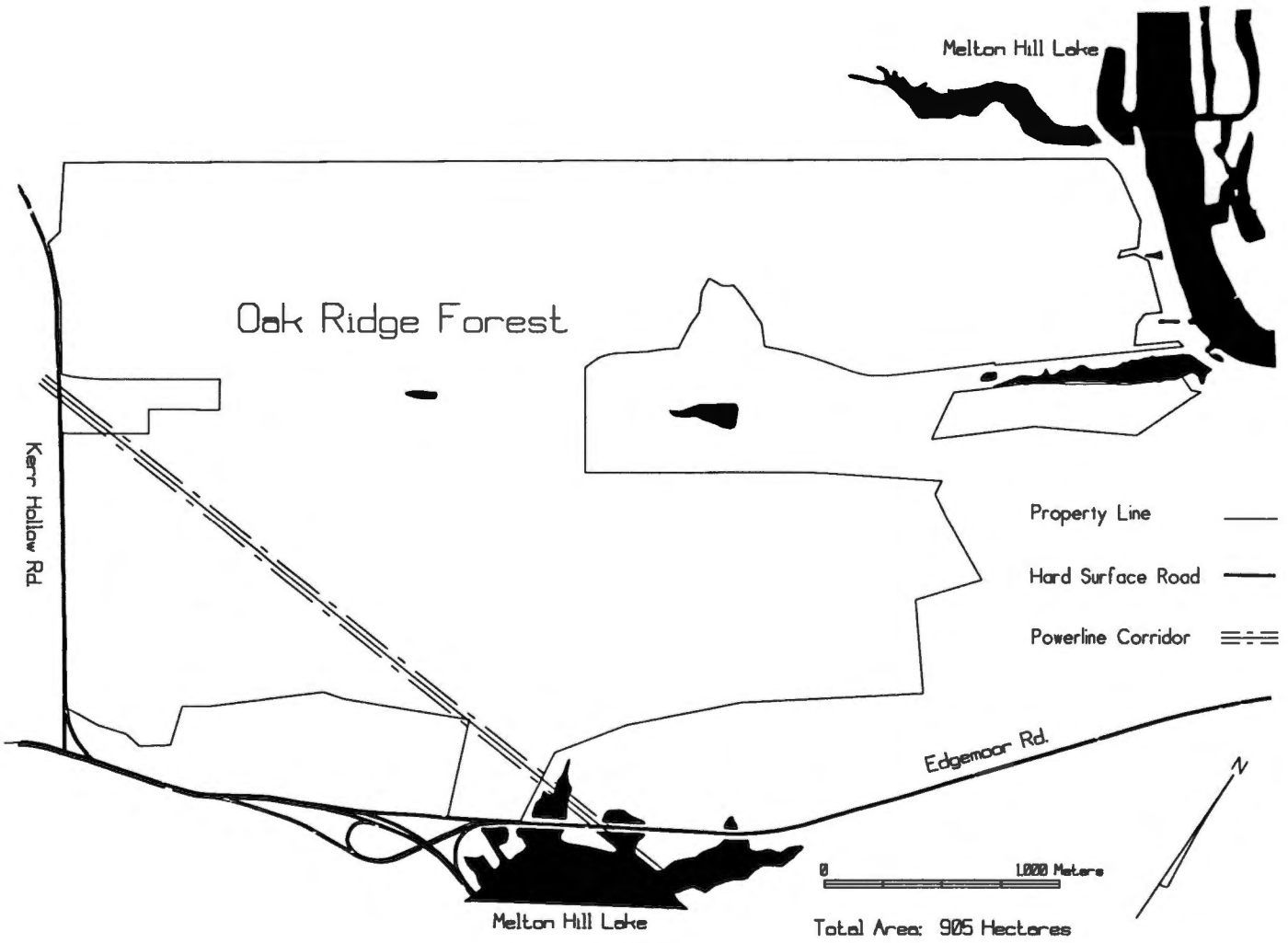


Figure 2. Oak Ridge Forest in Oak Ridge, Tennessee.

Summer and winter temperatures average 24.2 C and 5.3 C, respectively. Rainfall is usually well distributed throughout the year, averaging 121 cm per year (Univ. Tenn. For. Exp. Stn. 1993). Total annual precipitation was lower than normal in 1992 and near normal in 1993 (Moneymaker 1971; Natl. Oceanic and Atmospheric Admin., Oak Ridge, unpubl. data). Rainfall was high in 1994 relative to the other 2 study years (Table 1). Mean seasonal temperatures were similar across years, except for an unusually warm fall-winter 1991-1992.

The Oak Ridge Forest was owned by the United States Atomic Energy Commission from 1942 to 1962. The University of Tennessee acquired the property in 1962, and has since protected the Forest from fire. Timber harvest has been limited to small portions of the Forest and to salvage cuts following windthrow or southern pine beetle (*Dendroctonus frontalis*) infestation. The Oak Ridge Forest's Arboretum receives thousands of visitors annually; it was identified as an official Wildlife Observation Area by the Tennessee Wildlife Resources Agency in 1993 (Hamel 1993).

The powerline corridor containing the 2 ROWs is adjacent to upland hardwood and mixed pine-hardwood stands, and regenerating clearcuts (Figure 3). The deciduous forest stands are composed principally of 2-aged oak-hickory groups: a 70-90-year age-group and a 100-120-year age-group. Dominant pretreatment tree species on the ROWs included red maple (*Acer rubrum*), wild black cherry, black gum (*Nyssa sylvatica*), sassafras, black oak (*Q. velutina*), white oak (*Q. alba*), shagbark hickory (*Carya ovata*), and short-leaf pine (*Pinus echinata*). The most prevalent shrubs were blackberries (*Rubus* spp.) and sumacs (*Rhus copallina* and *R. glabra*), while low-bush

Table 1. Total seasonal precipitation (cm) and mean temperatures (C) in Oak Ridge, Tennessee, fall 1991-summer 1994.[a]

	Precipitation		Temperature	
Period	Fall-Winter	Spring-Summer	Fall-Winter	Spring-Summer
Oct 1991-Sep 1992	47.73	50.93	9.68	19.92
Oct 1992-Sep 1993	104.30	56.61	7.33	21.62
Oct 1993-Sep 1994	93.48	94.33	7.31	20.17

[a] Source: National Oceanic and Atmospheric Administration, Oak Ridge, unpublished data.

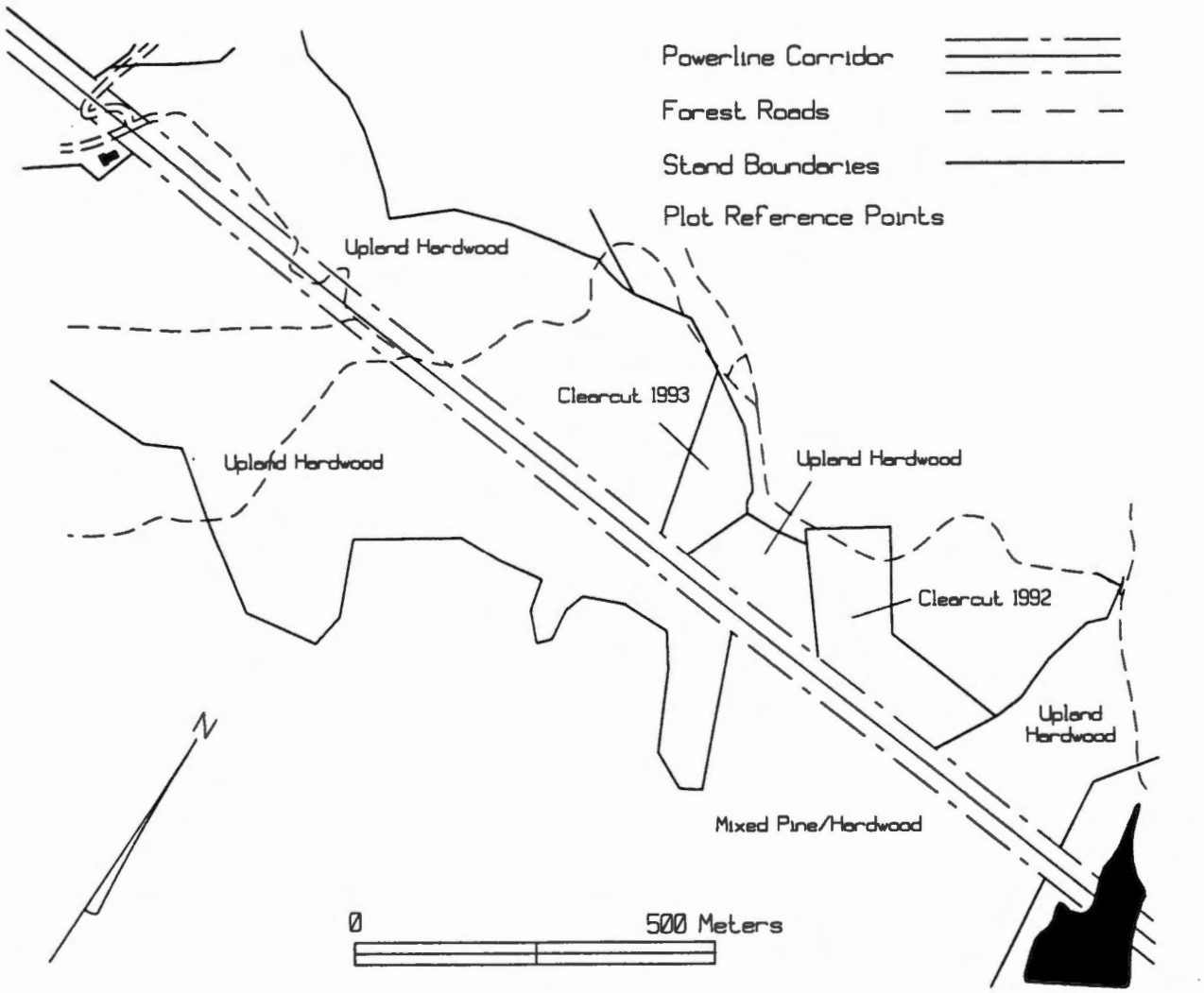


Figure 3. Powerline corridor on Oak Ridge Forest in Oak Ridge, Tennessee.

blueberry (*V. angustifolium*) and bicolor lespedeza were locally abundant in some areas. The most abundant vine species on the corridor were Japanese honeysuckle and greenbrier (*Smilax* spp.); Virginia creeper, grapes (*Vitis* spp.), and poison ivy (*Toxicodendron radicans*) were occasional residents.

Common grasses and sedges on the ROWs at this study's initiation included broomsedge, willow grass (*Microstegium vimineum*), panic grasses, purple top, silver plume grass (*Erianthus alopecuroides*), and sedges (*Carex* spp.). Goldenrods (*Solidago* spp), tick trefoils (*Desmodium* spp.), partridge-pea (*Cassia fasciculata*), yellow wood-sorrel (*Oxalis stricta*), crownbeards (*Verbesina* spp.), and bedstraw (*Galium* spp.) were the most common forbs. Christmas fern (*Polystichum acrostichoides*), lobed spleenwort (*Asplenium pinnatifidum*), and ebony spleenwort (*Asplenium platyneuron*) were the most prevalent ferns.

CHAPTER 4

MATERIALS AND METHODS

Research Design

Vegetation was measured on the study area prior to tebuthiuron application (October 1992) and for 2 years following treatment (October 1993, 1994). I monitored trees and shrubs using a repeated measures design (Cain and Castro 1959) because of the difficulty in creating a true control with which to compare treatment effects; thus I used the same transects before and after tebuthiuron treatment. Herbaceous and low-growing vegetation monitoring followed a stratified-random sampling scheme to ensure sampling from similar micro-site conditions and plant community types over time (Husch et al. 1982). Repeated measures on these plots were not possible because of consumptive (clip-and-weigh) measurements.

Plot Locations and Demarcation

I used fixed reference points to establish strip transects and quadrats along the 2 ROWs. I selected 30 locations using restricted randomization (>16 m apart) for locating reference points in the utility corridor (Cain and Castro 1959, Kershaw 1973). At each of the 30 locations, I marked 1 reference point directly beneath the interior electrical conducting wire on each of the 2 ROWs, for a total of 60 reference points. These points served as beginning points for strip transects and functioned as reference

markers for locating quadrats (Figure 4). Steel rods (2 cm × 1 m), sheathed in white polyvinyl chloride pipe with plot numbers attached, permanently identified reference points. I recorded aspect and slope at each point. Fifteen m (corrected for slope) was measured east of each reference point for permanently marking strip-transect endpoints.

I established 60 1.5- × 15-m (22.5 m^2) strip transects (Cain and Castro 1959, Peevy 1975, Gysel and Lyon 1980) extending longitudinally (east-west) down the corridor to quantify trees and shrubs. I measured herbaceous plants and vines using 60 1- × 1-m quadrats (Cain and Castro 1959, Pettit 1979, Bonham 1989).

Tebuthiuron Treatment

The 2 ROWs were aerially treated with tebuthiuron pellets at the rate of 6.8 kg a.i./ha on 29 October 1992, by a helicopter equipped with a modified Simplex seeder (Simplex Manufacturing Co., Portland, Oregon). Untreated buffer strips (~7.5 m wide) were left on the north and south sides of each ROW to protect vegetation off the ROWs and to avoid disturbing the vegetation between the ROWs. Six (3 per ROW) 0.85- × 0.8-m (0.7 m^2) systematically-located herbicide-collection plots were used to estimate actual application rates on the ground.

Vegetation data were collected at each of the 60 reference points from 1992 to 1994. The areas surrounding 6 reference points at the ends of the treatment zone on ROW 2 were omitted from tebuthiuron treatment due to their proximity to drainages;

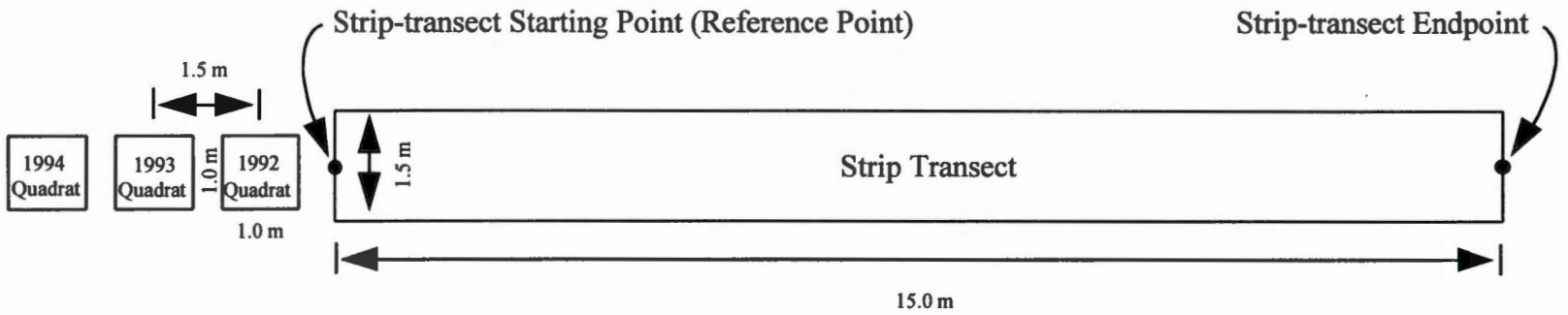


Figure 4. Strip-transect and quadrat configuration for vegetation sampling on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

data from these 6 points were excluded from analyses. I used the plant nomenclature of Wofford (1989) for woody and herbaceous plants.

Photographic Monitoring

I recorded the visual appearance of vegetative conditions on the ROWs at 4-6 month intervals with 35-mm color photographs (Pentax single-lens reflex camera with a 50-mm lens). Five pairs of plot reference points along the utility corridor were randomly selected from which to take photographs. At each reference point, I photographed ROW vegetation in eastern and western directions (parallel to the interior electrical conducting wires) from 2.5 m above the ground.

Tree and Shrub Monitoring

Density

I quantified the tree and shrub components on ROWs by carrying a 1.5-m pole (Gysel and Lyon 1980) the length of each strip transect and tallying the number of stems encountered of each species. I counted any tree or shrub with a living part encountered in the vertical plane of the pole (Greig-Smith 1957, Cain and Castro 1959, Kershaw 1973). Shrubs included sumacs, blueberry, blackberries, bicolor lespedeza, multiflora rose (*Rosa multiflora*), and azalea (*Rhododendron* spp.). To increase sampling efficiency, when I counted 30 stems of a species on a transect, the distance from the reference point was noted and the species was no longer counted on the transect. Stem densities for these abundant species were then extrapolated for the

entire strip transect by multiplying 30 by the ratio of the transect length (15 m) to the measured distance.

I tallied clumps of trees and shrubs to monitor stump sprouting. A clump was defined as 2 or more stems growing from the same stump or bole at or slightly above (≤15.24 cm) the ground's surface. When I encountered any part of a clump within a transect, the number of stems in the entire clump were counted. I ceased counting stems in clumps of a species after encountering 3 clumps of that species on a transect.

Frequency of Occurrence, Richness and Dominance

I defined frequency of occurrence as the percent of transects on which a given species was recorded. Richness was defined as the total number of tree and shrub species recorded on a transect. Dominance indices in forest stands are calculated using relative frequency, relative density (proportion of stems of 1 species per unit area to stems of all species per unit area), and relative dominance (basal area) (Cottam 1949, Cain and Castro 1959). I modified this dominance index for this study by substituting relative mean species height (mean height of a species/max. mean species height for any species) for basal area. For each species, the dominance index was the sum of the relative density (%), frequency of occurrence (%), and relative mean species height (%) divided by 3.

Height

I estimated the height of the tallest living tree or shrub and the mean height for tree and shrub species present on transects to the nearest 0.25 m. Plants were considered living if any plant part, such as a leaf, bud, or stem, was determined to be living.

Vertical Cover

I quantified percent vertical cover using a 0.3 m × 1.5 m cover board with a 20-cell grid (Nudds 1977, Scifres and Koerth 1986). I recorded 4 cover estimates per strip transect (n = 240); 2 were taken from each reference point (transect starting point) and 2 from each endpoint. At each transect starting point and endpoint, I positioned the cover board facing south and east (perpendicular and parallel to the strip transects), respectively, and recorded percent cover while kneeling 3 m away from the board. I estimated the percent of the board obscured by plant material to the nearest percent.

Herbaceous and Low-growing Vegetation Monitoring

Density and Ground Cover

I located quadrat centers 1.5-m west of reference markers in 1992 and 1-m further west of the previous year's quadrat location in 1993 and 1994. In the event of an obvious disturbance (such as a large rock outcropping or a road) on a quadrat location, quadrats were relocated 1 m closer to the center line of the ROW (Oosting

1956, Cain and Castro 1959, Kershaw 1973). I counted the number of plants by species within a square 1- × 1-m frame (Cain and Castro 1959, Daubenmire 1968). Grasses and sedges were tallied by culms. I estimated percent ground cover of each species within each quadrat (Cain and Castro 1959, Kershaw 1973). I only counted plants originating within the square, except for Japanese honeysuckle and willow grass, for which only percent cover was recorded due to difficulty in establishing stem origination points (Greig-Smith 1957, Cain and Castro 1959, Kershaw 1973).

Frequency of Occurrence, Richness, and Dominance

Frequency of occurrence was defined as the percent of quadrats on which a herbaceous plant or vine species was encountered. Richness was defined as the total number of herbaceous plant and vine species encountered in a quadrat. I calculated dominance indices in herbaceous plant and vine stands by summing the relative density (%), frequency of occurrence (%), and relative ground coverage (%), and dividing by 3 (Curtis 1947, Cain and Castro 1959).

Biomass

I monitored plant biomass using a clip-and-weigh procedure (Scifres and Mutz 1978, Doerr and Guthery 1983). I clipped all living plants originating within the 1-m^2 quadrats to ground level (except Japanese honeysuckle and willow grass, for which only the parts of the plants occurring on or above the plot were clipped). I sorted clipped samples into categories: trees, shrubs, vines, forbs, and grasses and sedges (Cain and Castro 1959, Shafer 1963, Higgins et al. 1994). I classified greenbrier,

Japanese honeysuckle, poison ivy and Virginia creeper as woody vines. I considered ferns and sericia (*Lespedeza cuneata*) to be forbs. I stored samples in a freezer at -3.8 C. I oven-dried samples at 60 C until they attained a constant weight ±1% (~24-48 hours depending upon woody content). I weighed samples immediately after drying to the nearest g.

Statistical Analyses

I analyzed density of trees and shrubs, maximum stem height, and vertical cover data using repeated measures analysis of variance (ANOVA) and paired *t*-tests (Ray 1982, Ott 1988). I analyzed tree and shrub mean species density data and variation in treatment effects by slope with Wilcoxon rank-sum tests with Bonferroni adjustments to the α decision criterion. I analyzed frequency of occurrence data for woody and herbaceous plants, and differences in treatment effects by aspect using chi-squared tests with Bonferroni adjustments (Ray 1982). Only the 10 most frequently occurring species from tree and shrub, and herbaceous plant and vine groups, respectively, were analyzed for differences to control family-wise error rates. I used ANOVA and *t*-tests to analyze density of forbs, ferns, grasses and sedges, and vines, ground cover data, and biomass data.

Research Hypotheses

I tested the following research hypotheses:

1. Tree densities decreased after tebuthiuron treatment;
2. Shrub densities decreased after tebuthiuron treatment;
3. Tree species' frequencies of occurrence on strip transects decreased after tebuthiuron treatment;
4. Shrub species' frequencies of occurrence on strip transects decreased after tebuthiuron treatment;
5. Maximum tree or shrub heights on transects decreased after tebuthiuron treatment;
6. Densities of vines decreased after tebuthiuron treatment;
7. Percent ground cover of vines decreased after tebuthiuron treatment;
8. Densities of forbs, ferns, and grasses and sedges increased after tebuthiuron treatment;
9. Percent ground cover of forbs, ferns, and grasses and sedges increased after tebuthiuron treatment;
10. Vertical cover decreased after tebuthiuron treatment;
11. Dry weights of trees decreased after tebuthiuron treatment;
12. Dry weights of shrubs decreased after tebuthiuron treatment;
13. Dry weights of vines decreased after tebuthiuron treatment;
14. Dry weights of grasses and sedges increased after tebuthiuron treatment;
15. Dry weights of forbs increased after tebuthiuron treatment; and

16. Species richness for woody and herbaceous species decreased after tebuthiuron treatment.

CHAPTER 5

RESULTS

Tebuthiuron Treatment

Herbicide-collection plots received from 0.93 to 16.18 kg a.i./ha of tebuthiuron; the mean application rate observed on collection plots was 6.35 kg a.i./ha. Mean tebuthiuron rate measured on collection plots was 10.11 and 2.58 kg a.i./ha for ROWs 1 and ROW 2, respectively. Based on this very limited sampling, treatment appeared to be heavy on ROW 1 and light on ROW 2.

A few trenches and steep slope bases showed evidence of minor herbicide runoff, with bare ground or sparse cover 1-year after treatment. However, no systematic variations in treatment effects on vegetation by aspect or slope were observed (Bonferroni-adjusted $\alpha = 0.001$).

Trees and Shrubs

Density

Tree densities (single stems and stems in clumps) decreased annually on both ROWs following tebuthiuron treatment ($P \leq 0.001$). Mean pretreatment tree density was 18,993 and 12,880 stems/ha on ROW 1 and 2, respectively (Table 2). Mean tree density on ROW 1 decreased to 8,345 stems/ha in 1993 and to 904 stems/ha in 1994. On ROW 2, mean tree density decreased to 8,219 in 1993 and to 1,981 stems/ha in

Table 2. Density (stems/ha) of trees and shrubs before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

Species Group[a]	ROW	n	Year					
			1992		1993		1994	
			$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Tree	1	30	18993Aa[b]	2060	8345Ab	1833	904Ac	178
	2	24	12880Ba	1627	8219Ab	1888	1981Bc	320
Shrub	1	30	27397Aa	2716	4049Ab	2419	12340Ac	5653
	2	24	18079Aa	2563	5507Ab	2171	7354Ab	2535

[a]Density differed by year for trees and shrubs (repeated measures ANOVA; trees: year effect $F = 64.14$, $P < 0.001$, df = 2, ROW effect $F = 1.10$, $P = 0.298$, df = 1; shrubs: year effect $F = 27.60$, $P < 0.001$, df = 2, ROW effect $F = 1.20$, $P = 0.279$, df = 1).

[b]For each species group, means within columns followed by different uppercase letters are different (paired t-test, $P < 0.05$); means within rows followed by different lowercase letters are different (paired t-test, $P < 0.05$).

1994. The density of many individual dominant tree species appeared to decline after treatment, but most changes failed to be significant after Bonferroni adjustment (Table 3). Only densities of shagbark hickory, black gum and wild black cherry decreased. Densities of yellow poplar, sourwood (*Oxydendrum arboreum*), flowering dogwood, red bud and other tree species did not decrease.

Mean shrub density (single stems and stems in clumps) across ROWs declined from pretreatment to 1 year post-treatment ($P < 0.001$), but mean shrub density increased from 1993 to 1994 on ROW 1 ($P < 0.001$; Table 2). Pretreatment shrub densities were 27,397 and 18,079 stems/ha on ROWs 1 and 2, respectively. Mean shrub density 2-years post-treatment, 12,340 and 7,354 stems/ha on ROWs 1 and 2, respectively, was lower than pretreatment ($P < 0.001$). Most shrubs on ROWs across years were blackberries or sumacs (Table 3); densities of each of these species decreased on both ROWs after treatment. Density of less dominant shrubs, such as bicolor lespedeza and blueberry, did not differ after treatment ($P > 0.02$; $\alpha = 0.0008$).

The density of tree clumps decreased on both ROWs 1-2 years following tebuthiuron treatment ($P > 0.001$), while shrub clumps decreased only on ROW 1 ($P = 0.031$; Table 4). Tree clump density decreased 99% on ROW 1 and 95% on ROW 2 from 1992 to 1994. On ROW 1, shrub clumps decreased in density by 78%. The most dramatic changes in tree clump densities occurred 1993-1994, probably due to the death of trees affected by tebuthiuron by 1994 that were still living during 1993 sampling.

Table 3. Density (stems/ha) of most dominant tree and shrub species before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee.

			Year					
			1992		1993		1994	
Species	ROW	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Blackberries	1	30	11782a[a]	1567	904b	414	7326b	3120
	2	24	10078a	2166	2870b	1457	6687ab	2519
Winged Sumac	1	30	10882a	1110	30b	30	44ab	25
	2	24	2944a	784	0b	0	56ab	31
Smooth Sumac	1	30	1319a	358	0b	0	0ab	0
	2	24	2981a	666	259b	204	19ab	19
Red Maple	1	30	1442a	574	704a	392	193a	63
	2	24	2513a	882	2200a	930	852a	269
Shagbark Hickory	1	30	2022a	410	2289a	970	0b	0
	2	24	426a	210	93a	46	19a	19
Black Gum	1	30	2025a	507	874a	220	89c	62
	2	24	556a	211	370a	136	352b	120
Wild Black Cherry	1	30	2919a	893	1559b	1093	59b	28
	2	24	2111a	556	1074ab	616	0b	0
Black Oak	1	30	1394a	315	178ab	99	0b	0
	2	24	333a	123	315a	315	0a	0
Yellow Poplar	1	30	1661a	426	563a	261	89a	33
	2	24	1435a	501	389a	227	167a	64
Sourwood	1	30	868a	349	44a	44	0a	0
	2	24	896a	304	1686a	789	37a	37

Table 3. (continued)

Species	ROW	*n*	Year 1992 $\bar{x}$	1992 SE	1993 $\bar{x}$	1993 SE	1994 $\bar{x}$	1994 SE
Flowering Dogwood	1	30	426a	991	1201a	480	0a	0
	2	24	222a	167	0a	0	0a	0
Short Leaf Pine	1	30	341a	153	89a	50	15a	15
	2	24	481a	173	426a	143	56a	31
Carolina Buckthorn	1	30	44a	33	119a	119	0a	0
	2	24	648a	246	37a	37	19a	19
Sassafras	1	30	267a	167	267a	166	281a	145
	2	24	556a	213	500a	206	333a	163
Redbud	1	30	665a	338	0a	0	178a	106
	2	24	1461a	703	296a	296	56a	31
White Oak	1	30	1729a	781	74a	74	0a	0
	2	24	74a	58	0a	0	0a	0
Virginia Pine	1	30	0a	0	0a	0	0a	0
	2	24	741a	423	704a	398	0a	0
Bicolor Lespedeza	1	30	3236a	1940	2938a	2035	3896a	3559
	2	24	611a	315	611a	315	0a	0
Eastern Redcedar	1	30	16a	16	16a	16	0a	0
	2	24	39a	39	39a	39	0a	0
Blueberry	1	30	133a	83	133a	83	1073a	1058
	2	24	135a	102	130a	98	37a	26

[a]For each species, means within rows followed by different lowercase letters are different (Wilcoxon rank-sum tests with Bonferroni corrections, $P < 0.0008$). ROW effects were excluded from analyses to minimize family-wise error rates.

Table 4. Density of clumped trees and shrubs (clumps/ha) before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

			Year					
			1992		1993		1994	
Species Group[a]	ROW	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Tree	1	30	3318Aa[b]	354	1644Ab	256	15Ac	15
	2	24	1481Ba	259	852Bb	179	75Bc	44
Shrub	1	30	207Aa	63	30Ab	21	44Ab	25
	2	24	111Ba	40	19Ab	19	185Bab	107

[a]Density differed by year and ROW for clumped trees (repeated measures ANOVA; trees: year effect $F = 80.32$, $P < 0.001$, df = 2, ROW effect $F = 12.07$, $P < 0.010$, df = 1; shrubs: year effect $F = 3.22$, $P = 0.438$, df = 2, ROW effect $F = 0.070$, $P = 0.798$, df = 1).

[b]For each species group, means within columns followed by different uppercase letters are different (paired *t*-test, $P < 0.05$); means within rows followed by different lowercase letters are different (paired *t*-test, $P < 0.05$).

Frequency of Occurrence and Richness

Prior to treatment, the most frequently occurring tree species across transects were wild black cherry (70.4%), red maple (63.0%), and black gum (55.6%) (Table 5). Eight of the 10 most frequently occurring tree and shrub species were found on fewer transects after treatment ($P < 0.0001$); red maple and yellow poplar frequencies of occurrence were not reduced after treatment ($P = 0.007$ and 0.0009, respectively; Bonferroni-adjusted $\alpha = 0.0001$). The most frequently encountered tree species on transects in 1994 were red maple (37%), yellow poplar (24.1%), black gum (20%), sassafras (18.5%), and redbud (11.1%). The most frequently encountered shrub species prior to tebuthiuron treatment were blackberries (100%), winged sumac (83.3%), and smooth sumac (66.7%). Frequency of occurrence of each declined after treatment.

A total of 39 tree and shrub species was observed on transects across years (Tables A-1 and A-2). Mean number of tree and shrub species observed on transects decreased on both ROWs following tebuthiuron application ($P < 0.001$ for trees and shrubs) (Table 6). Mean tree richness on ROWs 1 and 2, respectively, was 5.7 and 5.5 species per transect before treatment, and 1.0 and 1.9 species per transect 2-years post-treatment. Mean shrub species richness on ROWs 1 and 2, respectively, were 2.7 and 3.0 pretreatment, and 0.9 and 1.2 2-years post-treatment.

Height and Dominance

Maximum tree or shrub heights on transects systematically declined following tebuthiuron application (Table 7). Mean maximum height on ROW 1 decreased from

Table 5. Transects (%) with most frequently occurring tree and shrub species before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way in eastern Tennessee.

	Year		
	1992	1993	1994
Species	Frequency of Occurrence	Frequency of Occurrence	Frequency of Occurrence
Blackberries	100a[a]	55.6b	75.9b
Winged Sumac	83.3a	1.9b	11.1b
Wild Black Cherry	70.4a	20.4b	7.4b
Smooth Sumac	66.7a	7.4b	1.9b
Red Maple	63.0a	55.6a	37.0a
Blackgum	55.6a	53.7a	20.4b
Shagbark Hickory	51.9a	35.2a	1.9b
Yellow Poplar	48.1a	22.2a	24.1a
Black Oak	42.6a	11.1b	0.0b
Sourwood	37.0a	14.8ab	1.9b

[a]For each species, frequencies of occurrence within rows followed by different lowercase letters are different (χ^2 test with Bonferroni correction, $P < 0.001$).

Table 6. Richness (species/22.5-m^2 transect) of trees and shrubs before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

			Year					
			1992		1993		1994	
Species Group[a]	ROW	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Trees	1	30	5.7Aa[b]	0.5	3.0Ab	0.3	1.0Ac	0.2
	2	24	5.5Ba	0.3	3.30Bb	0.3	1.9Bc	0.3
Shrubs	1	30	2.7Aa	0.1	0.7Ab	0.1	0.9Ab	0.1
	2	24	3.0Aa	0.2	1.3Bb	0.1	1.2Ab	0.1

[a]Richness differed by year for trees and shrubs and by ROW for shrubs (repeated measures ANOVA; trees: year effect $F = 143.79$, $P < 0.001$, df = 2, ROW effect $F = 0.75$, $P = 0.390$, df = 1; shrubs: year effect $F = 159.52$, $P < 0.001$, df = 2; ROW effect $F = 7.49$, $P = 0.009$, df = 1).

[b]For each species group, means within columns followed by different uppercase letters are different (paired *t*-test, $P < 0.05$); means within rows followed by different lowercase letters are different (paired *t*-test, $P < 0.05$).

Table 7. Maximum woody stem heights (m) and vertical cover (%) on 22.5m^2 transects before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

			Year					
			1992		1993		1994	
Variable[a]	ROW	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Max. ht.	1	30	2.24Aa[b]	0.25	1.74Ab	0.17	0.88Ac	0.09
	2	24	4.71Ba	0.44	2.88Bb	0.29	1.68Bc	.20
Vertical Cover	1	30	60Aa	4	15Ab	1	44Ac	2
	2	24	51Aa	4	23Bb	2	50Aa	3

[a]Max. ht. and vertical cover differed by year and max. ht. differed by ROW (repeated measures ANOVA; max. ht.: year effect $F = 35.21$, $P < 0.001$, df = 2, ROW effect $F = 29.12$, $P < 0.001$, df = 1; vertical cover: year effect $F = 81.15$, $P < 0.001$, df = 2; ROW effect $F = 0.65$, $P = 0.424$, df = 1).

[b]For each variable, means within columns followed by different uppercase letters are different (paired *t*-test, $P < 0.05$); means within rows followed by different lowercase letters are different (paired *t*-test, $P < 0.05$).

2.24 m in 1992 to 0.88 m in 1994 ($P = 0.0001$). Mean maximum height on ROW 2 decreased from 4.71 m in 1992 to 1.68 m in 1994 ($P = 0.0001$). Many of the tallest woody stems on transects in 1994 were shrubs, primarily blackberries.

Estimated mean heights for the most abundant tree and shrub species on transects also decreased after tebuthiuron treatment (Table 8). The average estimated heights for yellow poplar and black cherry, 2 of the tallest and fastest growing species on the corridor, dropped from 2.42 to 0.81 m and 2.60 to 0.43 m, respectively, on ROW 2 from 1992-1994. Estimated mean heights for blackberry, smooth sumac, and winged sumac all varied 1992 versus 1994.

The most dominant shrub and tree species on the utility corridor pretreatment were blackberries, sumacs, red maple, black cherry, shagbark hickory, black gum (Table 9). Several less dominant species, such as black oak, yellow poplar, and sourwood had density indices of 5 to 20 in 1992. Because some species and the majority of tree and shrub stems were eliminated in 1993 and 1994, post-treatment dominance was shared by fewer species. In 1994, blackberries, smooth sumac, and flowering dogwood were most dominant. Only yellow poplar, red maple and black gum had dominance scores of 5 to 20 in 1994.

Vertical Cover

Vertical cover decreased on both ROWs the first year following tebuthiuron application ($P = 0.0001$), but only vertical cover on ROW 1 remained lower 2-years

Table 8. Estimated heights (m) of most dominant tree and shrub species before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

			Year					
			1992		1993		1994	
Species[a]	ROW	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Blackberries	1	30	1.36a	0.07	0.22b	0.68	0.17b	0.03
	2	24	1.38a	0.06	0.76b	0.10	0.75b	0.09
Winged Sumac	1	30	1.11a	0.09	0.06b	0.04	0.07b	0.04
	2	24	0.82a	0.15	0.06b	0.06	0.14b	0.08
Smooth Sumac	1	30	0.50a	0.13	0.04b	0.04	0.00b	0.00
	2	24	2.55a	0.30	0.64b	0.22	0.42b	0.20
Red Maple	1	30	0.42a	0.09	0.11a	0.06	0.13a	0.04
	2	24	1.24a	0.24	0.80ab	0.15	0.38b	0.10
Shagbark Hickory	1	24	0.76a	0.16	0.43b	0.10	0.00b	0.00
	2	30	0.79a	0.24	0.33a	0.15	0.23a	0.14
Black Gum	1	30	0.60a	0.09	0.31ab	0.10	0.06b	0.04
	2	24	1.10a	0.28	0.34a	0.16	0.47a	0.15
Wild Black Cherry	1	30	1.16a	0.24	0.14b	0.08	0.07b	0.03
	2	24	2.60a	0.41	0.78ab	0.21	0.43b	0.24
Black Oak	1	24	0.66a	0.14	0.20ab	0.10	0.00a	0.00
	2	30	0.44a	0.17	0.08a	0.08	0.08a	0.08
Yellow Poplar	1	30	1.22a	0.38	0.27a	0.14	.010a	0.04
	2	24	2.42a	0.52	0.79a	0.26	0.81a	0.27
Sourwood	1	30	0.31a	0.10	0.06a	0.06	0.00a	0.00
	2	24	0.80a	0.20	0.57ab	0.18	0.01b	0.01

Table 8. (continued)

Species	ROW	n	Year 1992 $\bar{x}$	1992 SE	1993 $\bar{x}$	1993 SE	1994 $\bar{x}$	1994 SE
Flowering Dogwood	1	30	0.50a	0.13	0.28ab	0.10	0.00b	0.00
	2	24	0.38a	0.17	0.06a	0.06	0.07a	0.06
Shortleaf Pine	1	30	0.14a	0.06	0.00a	0.00	0.02a	0.02
	2	24	0.47a	0.13	0.07a	0.05	0.05a	0.03
Carolina Buckthorn	1	30	0.04a	0.04	0.05a	0.05	0.00a	0.00
	2	24	1.00a	0.29	0.15a	0.09	0.24a	0.13
Sassafras	1	30	0.20a	0.08	0.23a	0.13	0.12a	0.06
	2	24	1.26a	0.29	0.94a	0.21	0.68a	0.19
Redbud	1	30	0.39a	0.22	0.00a	0.00	0.04a	0.03
	2	24	1.51a	0.37	0.33a	0.17	0.25a	0.14
Virginia Pine	1	30	0.00a	0.00	0.00a	0.00	0.00a	0.00
	2	24	0.23a	0.10	0.06a	0.05	0.00a	0.00
Bicolor Lespedeza	1	30	0.22a	0.10	0.33a	0.07	0.11a	0.06
	2	24	0.27a	0.12	0.28a	0.07	0.00a	0.00
Eastern Redcedar	1	30	0.09a	0.06	0.03a	0.03	0.00a	0.00
	2	24	0.17a	0.08	0.25a	0.10	0.17a	0.16
Blueberry	1	30	0.04a	0.04	0.03a	0.02	0.04a	0.02
	2	24	0.05a	0.03	0.10a	0.05	0.03a	0.02

*For each species, means within rows followed by different lowercase letters are different (Wilcoxon rank-sum test with Bonferroni correction, $P < 0.0008$). ROW effects were excluded from analyses to minimize family-wise error rates.

Table 9. Modified dominance indices[a] of most dominant tree and shrub species before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

			Year		
			1992	1993	1994
Species	ROW	*n*	Dominance Index	Dominance Index	Dominance Index
Blackberries	1	30	33.9	13.6	21.6
	2	24	33.8	24.5	31.3
Winged Sumac	1	30	32.6	1.1	3.5
	2	24	22.5	0.0	4.2
Smooth Sumac	1	30	15.7	0.1	33.3
	2	24	31.0	5.7	1.5
Red Maple	1	30	16.8	1.1	10.3
	2	24	26.7	25.4	15.5
Shagbark Hickory	1	24	24.7	17.1	0.0
	2	30	26.5	5.6	1.4
Black Gum	1	30	24.6	23.6	3.5
	2	24	11.2	11.2	11.4
Wild Black Cherry	1	30	23.7	3.6	4.6
	2	24	24.0	11.5	0.0
Black Oak	1	24	18.0	5.7	0.0
	2	30	9.8	1.5	0.0
Yellow Poplar	1	30	17.0	8.0	6.9
	2	24	15.6	7.2	10.1
Sourwood	1	30	10.1	1.1	0.0
	2	24	15.4	10.1	1.4

Table 9. (continued)

Species	ROW	*n*	Year 1992 Dominance Index	Year 1993 Dominance Index	Year 1994 Dominance Index
Flowering Dogwood	1	30	14.7	8.0	33.3
	2	24	5.6	0.0	0.0
Shortleaf Pine	1	30	6.7	4.4	1.1
	2	24	14.0	14.0	4.2
Carolina Buckthorn	1	30	2.2	1.2	0.0
	2	24	12.7	1.4	1.4
Sassafras	1	30	6.3	6.9	4.7
	2	24	11.2	11.5	8.6
Redbud	1	30	5.7	0.0	3.4
	2	24	10.0	10.1	4.3
White Oak	1	30	9.11	1.1	0.0
	2	24	2.8	0.0	0.0
Virginia Pine	1	30	0.0	0.0	0.0
	2	24	7.0	7.1	0.0
Bicolor Lespedeza	1	30	4.7	4.9	3.8
	2	24	7.0	7.1	0.0
Eastern Redcedar	1	30	2.2	2.2	0.0
	2	24	5.6	5.6	0.0
Blueberry	1	30	3.3	3.4	2.4
	2	24	2.8	2.8	2.8

[a]Modified dominance index = (relative density + mean ht. of species/greatest mean ht. of any species + frequency of occurrence)/3. An index of 100 indicates highest dominance by a species.

post-treatment ($P = 0.006$) (Table 7). Vertical cover means across both ROWs for each successive year were 56%, 18%, and 46%, respectively.

Herbaceous Plants and Vines

Density and Ground Cover

Density of herbaceous plants dramatically increased following tebuthiuron treatment ($P < 0.001$), with densities increasing from 17.50 to 70.72 stems/m^2 from 1992 to 1994 across ROWs. Vines also increased across the study period ($P = 0.016$), but peaked in 1993 (Table 10). For all low-growing plants combined, densities increased by 74% on each ROW from 1992 to 1994 ($P < 0.001$).

Grasses and sedges, and forbs increased in density 1992-1994 ($P < 0.001$; Table 10). In 1992, forbs were only slightly less abundant (7.68 stems/m^2) on quadrats than grasses (8.59 stems/m^2) across ROWs. In 1994, grasses were much denser--mean forb density across ROWs was 19.29 stems/m^2, while mean grass density was 61.44 stems/m^2.

Ground cover of low-growing plants increased during years following tebuthiuron application ($P < 0.001$; Table 11). Mean ground cover for all species groups on quadrats in 1992 was 73% on ROW 1 and 62% on ROW 2. The same estimates rose to 84% and 101%, respectively, in 1993, and to 130% and 120% in 1994 (>100% cover was possible due to layering effect of low-growing species). Vine cover, comprised primarily of Japanese honeysuckle, decreased from 47.47% on ROW 1 pretreatment to 21.73% 2-years post-treatment ($P < 0.001$); vine cover did

Table 10. Densities (stems/m^2) of grasses and sedges, forbs, ferns, and vines before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

			Year					
			1992		1993		1994	
Species Group[a]	ROW	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Grasses /	1	30	8.63Aa[b]	2.43	29.93Aa	6.67	49.77Aa	7.97
Sedges	2	24	8.54Aa	1.97	29.42Ab	8.64	76.04Ab	6.39
Forbs	1	30	9.56Aa	1.59	45.40Ab	10.49	25.53Ab	4.45
	2	24	5.33Ba	0.98	28.54Ab	7.29	11.50Bc	2.69

Table 10. (continued)

Species Group	ROW	*n*	Year					
			1992		1993		1994	
			$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Ferns	1	30	0.17Aa	0.08	0.57Ab	0.19	0.67Ab	0.35
	2	24	0.33Aa	0.14	3.47Bb	0.68	1.90Ab	0.31
Vines	1	30	1.03Aa	0.22	6.33Ab	3.33	1.21Ac	0.53
	2	24	0.92Aa	0.28	2.33Ab	0.42	1.25Bb	0.16

[a]Density differed by year for grasses and sedges, forbs, ferns, and vines, and by ROW for grasses and sedges, and forbs (ANOVA; grasses and sedges: year effect $F = 16.25$, $P < 0.001$, df = 2, ROW effect $F = 0.02$, $P = 0.884$, df = 1; forbs: year effect $F = 13.13$, $P < 0.001$, df = 2, ROW effect $F = 5.74$, $P = 0.018$, df = 1; ferns: year effect $F = 3.00$, $P = 0.053$, df = 2, ROW effect $F = 4.52$, $P = 0.035$, df = 1; vines: year effect $F = 12.68$, $P < 0.001$, df = 2; ROW effect $F = 3.68$, $P = 0.057$, df = 1).

[b]For each species group, means within columns followed by different uppercase letters are different (paired *t*-test, $P < 0.05$); means within rows followed by different lowercase letters are different (paired *t*-test, $P < 0.05$).

Table 11. Ground cover (%) of forbs, grasses and sedges, ferns, and vines on quadrats before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

			Year					
			1992		1993		1994	
Species Group[a]	ROW	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Grasses /	1	30	10.84Aa[b]	3.64	30.95Ab	6.19	61.88Ac	5.52
Sedges	2	24	19.69Aa	5.85	61.88Ab	5.52	76.04Ac	6.40
Forbs	1	30	13.42Aa	3.12	31.83Ab	4.83	45.47Ab	6.30
	2	24	4.30Ba	1.18	45.47Ab	6.30	18.92Bb	4.09

Table 11. (continued)

			Year					
			1992		1993		1994	
Species Group	ROW	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Ferns	1	30	0.73Aa	0.46	0.52Ab	0.25	0.63Ab	0.32
	2	24	2.19Aa	1.19	3.72Aa	2.01	2.04Aa	0.97
Vines	1	30	47.47Aa	5.26	20.93Ab	4.72	21.73Ab	2.83
	2	24	36.49Aa	5.82	26.17Aa	4.25	18.92Aa	4.10

[a]Ground cover differed by year for grasses and sedges, forbs, ferns, and vines and by ROW for grasses and sedges, forbs, and ferns (ANOVA; grasses and sedges: year effect $F = 42.14$, $P < 0.001$, df = 2, ROW effect $F = 6.39$, $P < 0.001$, df = 1; forbs: year effect $F = 16.27$, $P < 0.001$, df = 2, ROW effect $F = 12.83$, $P = 0.018$, df = 1; ferns: year effect $F = 0.38$, $P = 0.682$, df = 2, ROW effect $F = 6.61$, $P = 0.011$, df = 1; vines: year effect $F = 12.68$, $P < 0.001$, df = 2, ROW effect $F = 0.17$, $P = 0.677$, df = 1).

[b]For each species group, means within columns followed by different uppercase letters are different (paired *t*-test, $P < 0.05$); means within rows followed by different lowercase letters are different (paired *t*-test, $P < 0.05$).

not differ on ROW 2 over the same interval ($P = 0.160$). Forb cover increased each successive year after treatment on ROW 1 ($P < 0.01$), but peaked in 1993 on ROW 2. Mean pretreatment forb cover on ROWs 1 and 2 was 13% and 4%, respectively, and 45% and 19%, respectively, 2-years post-treatment. Ground cover by grasses and sedges increased from 11% and 20% on ROWs 1 and 2, respectively, to 62 and 76%, respectively over the entire study period. Fern cover did not differ after tebuthiuron treatment.

Frequency of Occurrence, Richness and Dominance

Frequency of occurrence changed for only 2 of the 10 vines or herbaceous plants most frequently encountered across quadrats (Table 12). Frequencies of snakeroot (*Eupatorium aromaticum*) and broomsedge increased 1992-1994 ($P < 0.001$).

A total of 68 vine and herbaceous plant species were observed in quadrats across years (Tables A3-A5). Total species richness/m^2 for herbaceous plants and vines increased the first year post-treatment ($P < 0.001$), and remained higher than that of pretreatment sampling through 1994 ($P < 0.001$; Table 13). In 1992, mean richness/m^2 for herbaceous plants and vines on the corridor was 5.2 species; mean species richness/m^2 was 9.5 in 1994.

Many low-growing species were dominant on ROWs pre- and post-treatment (Table 14). Japanese honeysuckle, silver plume grass, goldenrod, panic grass, and sedges all had dominance indices >30 1992-1994. Broomsedge, snakeroot, hairy bush-clover, *Ruellia carolinensis*, and willow grass increased notably in dominance after treatment. Tick trefoils, greenbrier, and partridge-pea dominance indices

Table 12. Percent of quadrats with most frequently occurring herbaceous plant and vine species before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

	Year		
	1992	1993	1994
Species	Frequency of Occurrence	Frequency of Occurrence	Frequency of Occurrence
Japanese Honeysuckle	94.4a[a]	88.9a	83.3a
Silver Plume Grass	40.7a	59.3a	48.1a
Panicum commutatum	40.7a	37.0a	38.9a
Sedges	40.7a	31.5a	38.9a
Greenbrier	37.0a	40.7a	35.2a
Tick Trefoils	35.2a	22.2a	24.1a
Goldenrods	33.3a	44.4a	50.0a
Willow Grass	16.7a	25.9a	40.7a
Snakeroot	3.7a	20.4ab	44.4b
Broomsedge	3.7a	48.1b	61.1b

[a]For each species, frequencies of occurrence within rows followed by different lowercase letters are different (χ^2 test with Bonferroni correction, $P < 0.001$).

Table 13. Species richness (species/m^2) of herbaceous plants and vines (excluding Japanese honeysuckle) before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

			Year					
			1992		1993		1994	
Species Group[a]	ROW	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Herbaceous	1	30	4.80Aa[b]	0.54	8.20Ab	0.74	9.40Aa	0.95
Plants	2	24	4.33Aa	0.47	7.33Ab	0.78	6.71Ab	0.65
Vines	1	30	0.67Aa	0.12	1.43Ab	0.14	1.37Ab	0.16
	2	24	0.54Aa	0.12	1.50Ab	0.17	1.25Bb	0.16

[a]Richness differed by year for herbaceous plants and vines and by ROW for herbaceous plants (ANOVA; herbaceous plants: year effect $F = 10.48$, $P < 0.001$, df = 2, ROW effect $F = 4.10$, $P = 0.045$, df = 1; vines: year effect $F = 19.51$, $P < 0.001$, df = 2, ROW effect $F = 0.24$, $P = 0.627$, df = 1).

[b]For each species group, means within columns followed by different uppercase letters are different (paired *t*-test, $P < 0.05$); means within rows followed by different lowercase letters are different (paired *t*-test, $P < 0.05$).

Table 14. Dominance indices[a] of most dominant herbaceous plant and vine species before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

			Year		
			1992	1993	1994
Species	ROW	*n*	Dominance Index	Dominance Index	Dominance Index
Japanese Honeysuckle	1	30	33.6	29.0	27.8
	2	24	29.4	30.6	27.8
Asters	1	30	30.0	4.4	5.6
	2	24	1.4	1.4	1.4
Panic Grasses	1	24	13.4	16.7	24.5
	2	30	19.5	18.1	11.2
Silver Plume Grass	1	30	15.6	23.4	16.7
	2	24	11.1	15.3	15.3
Sedges (*Carex* spp.)	1	30	12.3	13.4	14.5
	2	24	15.3	7.0	11.2
Goldenrods	1	30	14.5	16.7	20.0
	2	24	6.9	12.5	12.5
Partridge-Pea	1	30	13.4	1.1	3.3
	2	24	2.8	0.0	1.4
Greenbrier	1	30	13.3	14.5	13.3
	2	24	11.1	12.5	9.7
Tick Trefoils	1	30	13.3	7.8	11.1
	2	24	9.8	6.9	4.2
Bedstraw	1	24	12.2	12.2	15.6
	2	30	4.2	6.9	2.8

Table 14. (continued)

Species	ROW	*n*	Year 1992 Dominance Index	Year 1993 Dominance Index	Year 1994 Dominance Index
Willow Grass	1	24	3.3	6.5	10.0
	2	30	8.4	12.6	18.2
Barren Strawberry	1	30	6.7	5.6	5.6
	2	24	4.2	6.9	2.8
Hairy Bush-Clover	1	24	5.6	5.6	10.0
	2	30	5.6	4.2	9.7
Ebony Spleenwort	1	30	1.1	4.4	5.6
	2	24	5.6	5.6	6.9
Broomsedge	1	24	0.0	17.8	26.9
	2	30	2.8	13.9	12.6
Sericea	1	24	2.2	4.4	10.0
	2	30	2.8	2.8	5.6
Snakeroot	1	24	2.2	4.2	16.7
	2	30	2.2	1.1	12.5
Milk Pea	1	30	0.1	11.1	15.5
	2	24	0.1	11.1	5.6
Ruellia carolinensis	1	30	0.0	1.1	6.7
	2	24	0.0	1.4	11.1
Wintercress	1	30	0.0	17.9	0.0
	2	24	0.0	16.8	1.4

*Dominance index = (relative density + frequency of occurrence + relative coverage)/3. An index of 100 indicates highest dominance by a species.

decreased after treatment. Asters were dominant on ROW 1 before treatment but declined 1- and 2-years post-treatment. Wintercress (*Barbarea* spp.) and milk pea (*Galactia volubilis*) spiked in dominance in 1993, but exhibited little dominance in either 1992 or 1994.

Biomass

Trees and vines comprised the bulk of dry weights for clip-and-weigh samples in 1992 (Table 15). Corresponding to the age and height differences on ROWs (Table 4), trees from quadrats on ROW 2 weighed substantially more (63%) on average. No shrubs occurred (by chance) on ROW 1 quadrats in 1992. Mean tree biomass decreased 99% on ROW 1 quadrats ($P < 0.001$) and 97% on ROW 2 quadrats ($P < 0.001$) from 1992 to 1994. Vine weights decreased 86% ($P < 0.001$) and 74% ($P < 0.001$) on the 2 ROWs' quadrats, respectively, over the 2-year interval.

Forb biomass on quadrats declined on ROW 1 the first year post-treatment ($P = 0.002$). ROW 1 showed a net loss in forb biomass 1992 versus 1994 ($P = 0.024$), but weights of forbs on ROW 2 did not differ ($P = 0.290$). Mean grass biomass on ROW 1 in 1994 approached that of trees in 1992 on the same site.

Photographic Monitoring

Appearances of both ROWs showed marked changes following tebuthiuron treatment (Figure 5). Pretreatment ROWs were visually brush-dominated. The dominance shift in favor of forbs, grasses, and sedges was visually apparent.

Table 15. Dry weights (g) of trees, shrubs, vines, forbs, and grasses and sedges before and 2 years after tebuthiuron treatment[a] on 2 powerline rights-of-way (ROWs) in eastern Tennessee.

Species Group	ROW	*n*	Year					
			1992		1993		1994	
			$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Trees	1	30	2578Aa[b]	571	4Ab	3	24Ac	8
	2	24	6883Aa	2676	354Ab	310	179Ab	94
Shrubs	1	30	0Aa	0	1Aa	1	78Ab	26
	2	24	208Aa	179	32Aa	32	102Aa	36

Table 15. (continued)

Species Group	ROW	n	Year 1992 $\bar{x}$	1992 SE	1993 $\bar{x}$	1993 SE	1994 $\bar{x}$	1994 SE
Vines	1	30	1494Aa	152	225Ab	48	210Ab	31
	2	24	1816Aa	257	310Ab	681	473Bb	94
Forbs / Ferns	1	30	1088Aa	273	189Ab	30	769Ac	148
	2	24	376Ba	104	104Bb	21	255Ba	53
Grasses / Sedges	1	30	315Aa	73.3	880 Aa	31	2073Ac	310
	2	24	331Aa	69.8	1075Ab	205.5	2398Ac	270.9

[a]Mean dry weights varied by year for trees, shrubs, vines, grasses and sedges, and forbs and ferns, and by ROW for vines and forbs (ANOVA; trees: year effect $F = 12.46$, $P < 0.001$, df = 2, ROW effect $F = 3.74$ $P = 0.055$, df = 2; shrubs: year effect $F = 0.83$, $P = 0.440$, df = 2, ROW effect $F = 2.48$, $P = 0.1175$, df = 2; vines: year effect $F = 75.94$, $P < 0.001$, df = 2, ROW effect $F = 4.67$, $P = 0.032$, df = 2; forbs: year effect $F = 8.93$, $P < 0.001$, df = 2, ROW effect $F = 12.87$, $P < 0.001$, df = 2; grasses and sedges: year effect $F = 38.96$, $P < 0.001$, df = 2, ROW effect $F = 0.99$, $P = 0.321$, df = 2).

[b]For each species group, means within columns followed by different uppercase letters are different (paired t-test, $P < 0.05$); means within rows followed by different lowercase letters are different (paired t-test, $P < 0.05$).



ROW 1 in October 1992 (Pretreatment)



ROW 1 in October 1994 (Post-treatment)

Figure 5. Appearance of vegetation before and 2 years after tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.



ROW 2 in October 1992 (Pretreatment)



ROW 2 in October 1994 (Post-treatment)

Figure 5. (continued)

CHAPTER 6

DISCUSSION

Tests of Research Hypotheses

Most of the research hypotheses for trees, shrubs and herbaceous plant responses were accepted. Post-treatment shrub clump density, vine density, fern density, vertical cover, shrub biomass, forb biomass, and species richness responses were different than expected (Table 16).

I rejected the research hypotheses for pretreatment versus 2-years post-treatment that: mean vine density decreases following tebuthiuron treatment, mean fern density increases, vertical cover decreases, shrub dry weights decrease, forb dry weights increase, and vine and herbaceous species richness decrease. An explanation of each hypothesis test result follows.

1. Mean density of trees (both single stems and clumps for trees decreased on both ROWs following tebuthiuron treatment ($P < 0.001$).

2. Mean density of shrubs (single stems) decreased on both ROWs following tebuthiuron treatment ($P < 0.001$). The changes in tree and shrub densities were consistent with previous findings (Pettit 1979, Doerr and Guthery 1983, Jones and Pettit 1984). Other studies have documented similar post-treatment decreases in trees (Myers 1984) and tree crown cover (Peevy 1975). Mean density of shrub clumps increased in successive years following treatment ($P < 0.001$ and $P < 0.001$ for ROWs

Table 16. Hypothesis test results for vegetation changes following tebuthiuron treatment on 2 powerline rights-of-way (ROWs) in eastern Tennessee, 1992-1994.

Research Hypothesis		Test Result	Comments
1.	Tree density decreased	Failed to reject	Single stems and clumps decreased;
2.	Shrub density decreased	Failed to reject	Single stems decreased, clumps increased
3.	Tree species frequencies of occurrence decreased	Failed to reject	8 of 10 most frequently occurring tree and shrub species
4.	Shrub species frequencies of occurrence decreased	Failed to reject	decreased
5.	Maximum tree or shrub height decreased	Failed to reject	
6.	Vine density (excluding Japanese honeysuckle) decreased	Rejected	Increased 1992-1993; increased 1992-1994 on ROW 2
7.	Percent ground cover of vines decreased	Failed to reject	
8.	Herbaceous plant density increased	Failed to reject	
9.	Percent ground cover of herbaceous plants increased	Failed to reject	
10.	Vertical cover decreased	Rejected	Decreased 1992-1993, but decreased 1992-1994 on ROW 1 only
11.	Tree dry weight decreased	Failed to reject	
12.	Shrub dry weight decreased	Rejected	Increased 1992-1993; increased 1992-1994 on ROW 1
13.	Vine dry weight decreased	Failed to reject	
14.	Grass and sedge dry weight increased	Failed to reject	
15.	Forb dry weight increased	Rejected	Decreased 1992-1993; decreased 1992-1994 on ROW 1 only
16.	Species richness decreased	Rejected	Tree and shrub richness decreased; vine and herbaceous plant richness increased

1 and 2, respectively). This may have resulted from hardier plants sprouting multiple stems from the same bole because of the reduction in competition for light and nutrients by other shrub and tree stems.

3. Frequency of occurrence for 6 of the 8 most abundant trees decreased on both ROWs ($P < 0.001$). Only red maple and yellow poplar frequencies of occurrence were similar across years. Defazio (1986) observed changes in frequency of occurrence only for sweetgum and loblolly pine (*P. taeda*), which decreased, and sassafras, which increased, after tebuthiuron site-preparation in Georgia.

4. Frequency of occurrence for the most abundant shrubs (blackberries) decreased on both ROWs ($P < 0.001$). Hawthorn (*Crataegus* spp.) and lespedeza decreased on Georgia's Coastal Plain on treated versus control sites (Defazio 1986).

5. Mean maximum height for trees or shrubs on transects decreased on both ROWs ($P < 0.001$). Woody plant height responses to tebuthiuron have not previously been documented.

6. Mean density of vines increased on both ROWs 1992-1993 ($P < 0.001$). In 1994, mean vine density was greater on ROW 2 than the pretreatment mean ($P = 0.0480$), but mean vine density was marginally different from that of pretreatment on ROW 1 ($P = 0.051$). Japanese honeysuckle density was not monitored here, but honeysuckle decreased in other studies (Lade et al. 1974, Defazio 1986).

7. Mean percent ground cover for vines decreased after treatment on ROW 1 ($P < 0.001$) and ROW 2 ($P = 0.030$) 1992-1994.

8. Density of herbaceous plants increased 1 and 2 years post-treatment ($P < 0.001$). Species groups within the herbaceous plant category varied in response to tebuthiuron (Table 10). From 1992 to 1994, mean density of grasses and sedges increased ($P < 0.001$ for each ROW), and mean forb density increased ($P < 0.001$ for ROW 1 and P = 0.002 for ROW 2). These results agreed with results from studies on many other tebuthiuron-treated sites (Scifres and Mutz 1978, Sosebee et al. 1979, Scifres and Koerth 1986, Guthery et al. 1987, Defazio et al. 1988*a*). Few studies have reported grass decreases after treatment (Worsham et al. 1974, Christenson et al. 1974, Pettit 1979). Forb density increases following tebuthiuron treatment have not been previously been reported, although biomass, cover, or frequency of occurrence increases have been documented (Doerr and Guthery 1983, Scifres and Koerth 1986, Fulbright and Garza 1991, Thompson et al. 1991). In most studies, forb density tended to decrease after tebuthiuron treatment (Scifres and Mutz 1978, Pettit 1979, Sosebee et al. 1979, Scifres and Koerth 1986, Guthery et al. 1987).

Mean fern density pretreatment to post-treatment decreased on ROW 1 ($P = 0.022$) but not on ROW 2 ($P = 0.092$). Ferns may have been adversely affected due to deeper root penetration and tebuthiuron absorption compared to other, more shallowly-rooting herbaceous plants.

9. Total herbaceous ground cover increased each successive year ($P < 0.001$ and $P < 0.001$, respectively) following treatment on both ROWs. Ground cover responses to tebuthiuron in other studies appeared to vary by plant community (Doerr and Guthery 1983, Guthery et al. 1987).

10. Mean percent vertical cover decreased on both ROWs 1-year post-treatment ($P < 0.001$) and on ROW 1 over the 2-year period ($P = 0.006$). As with treated mixed brush stands in Texas, the reduction in trees and shrubs caused screening cover on ROWs to decline (Scifres and Koerth 1986). Very low-growing shrub stands can produce greater vertical cover after treatment, however (Doerr and Guthery 1983). Two years after treatment, however, mean percent vertical cover was similar to the pretreatment mean on ROW 2 ($P = 0.668$). The increase in vertical cover from 1993-1994 (Table 7) was probably due to the proliferation of grasses and more dominant, taller forbs in the absence of tree and shrub competition. This is evidenced by the concomitant increase in forb biomass 1993-1994 on both ROWs (Table 15). Also, many dead tree and shrub stems on ROW 2 were still standing in 1993 and 1994, while most dead tree and shrub stems on ROW 1 had broken or fallen to the ground by 1993 or 1994 (Tanner 1978). I observed many vines growing up standing, dead stems on ROW 2 in 1994. This may partially explain why mean vertical cover on ROW 1 did not recover the final year of sampling as much as vertical cover on ROW 2.

11. Mean dry weight of trees decreased on both ROWs 1992-1994 ($P < 0.001$ for ROW 1, and $P < 0.001$ for ROW 2). This change is reasonable in lieu of tree density decreases. Tree biomass also declined in Georgia post-treatment (Defazio 1986).

12. Post-treatment mean dry weight of shrubs differed from the pretreatment mean only on ROW 1 ($P = 0.003$), for which it increased. This probably resulted

from sampling error, since few shrubs were collected in quadrats in 1992. Differences in mean shrub weights 1992-1994 on ROW 2 was probably random variation ($P = 0.333$).

13. Mean dry weight of vines decreased on ROWs 1 and 2 ($P < 0.001$ and $P < 0.001$, respectively) 1992-1993 and remained lower than pretreatment mean weights through 1994 ($P < 0.001$). In Oklahoma and on the Georgia Coastal Plain, vine biomass was unchanged by tebuthiuron treatment (Defazio 1986, Thompson et al. 1991), but on the Georgia Piedmont Plateau, vine dry weights were lower on treated versus control sites (Defazio 1986).

14. Mean dry weight of grasses and sedges increased on ROWs 1 and 2 1- ($P = 0.023$ and $P = 0.001$, respectively) and 2-years ($P = 0.003$ and $P < 0.001$, respectively) following tebuthiuron treatment. These findings were consistent with those of several previous studies (Scifres and Mutz 1978, Cox et al. 1986, Defazio et al. 1988, Fulbright and Garza 1991).

15. Mean dry weight of forbs decreased 1 year after treatment on both ROWs ($P = 0.0018$ and $P = 0.014$ for ROWs 1 and 2, respectively). Mean dry weight of forbs differed 1992 versus 1994 on ROW 1 ($P = 0.024$) but not on ROW 2 ($P = 0.290$). Differential forb biomass responses have been observed in other areas as well (Thompson et al. 1991, Defazio 1986, Fulbright and Garza 1991).

16. Species richness for trees and shrubs decreased on both ROWs 1- and 2-years post-treatment ($P < 0.001$). This was probably due simply to the elimination of a large percentage of tree and shrub stems. Species richness of vines increased on

both ROWs the first post-treatment year ($P < 0.001$) and remained higher than pretreatment vine richness through 1994 ($P < 0.001$). Richness of herbaceous plants also increased across ROWs over the 2-year interval ($P < 0.001$). Guthery et al. (1987) and Scifres and Koerth (1986) reported decreases in herbaceous species richness after tebuthiuron treatment, while Scifres and Mutz (1978) observed little variation in species richness post-treatment.

Relatively few densities and estimated heights of dominant tree species significantly decreased because of the stringency of Bonferroni adjustments. Statistics with these corrections were extremely conservative and may predispose hypothesis test results to Type II errors--rejecting research hypotheses when they were true (Ott 1988). With Bonferroni adjustments, densities of only 7 of the 20 most dominant species significantly decreased on at least 1 ROW ($P < 0.0008$; Table 3). Heights decreased on both ROWs for blackberries, sumacs, and black cherry, and on 1 ROW for red maple, shagbark hickory, black gum, flowering dogwood, and sourwood ($P < 0.001$; Table 8).

Effects of Site Conditions and Application Rate

Rainfall is important in dissolving tebuthiuron pellets and carrying the chemical into the root zone of plants (Christenson et al. 1974, Lade et al. 1974). Rainfall following tebuthiuron application was probably adequate to carry tebuthiuron in solution to depths sufficient for plant root uptake. Rain fell 6 of the 14 days following application for a total of 9.65 cm (Natl. Oceanic Atmospheric Admin. 1995); bare

ground in narrow trenches and toward the base of a few steep slopes 1 year after treatment suggested that some lateral movement of tebuthiuron may have occurred. This was not confirmed by statistical analysis, however, in that I found no response differences by slope. Also, high rainfall during 1994 may have contributed to the high rates of increase in grass density, biomass, and frequency of occurrence, and forb biomass 1993-1994.

Soil texture and organic matter content are reportedly important in the activity of tebuthiuron (Chang and Stritzke 1977), but research suggests the chemical is effective on soil types ranging from sandy to clayey (Bovey et al. 1978, Pettit 1979, Doerr and Guthery 1983, Guthery et al. 1987, Defazio et al. 1988*a*, Fulbright and Garza 1991). The Fullerton series soil on my study area is well drained (Moneymaker 1981). This soil characteristic coupled with ample rainfall received post-treatment and during the 2 growing seasons thereafter probably carried tebuthiuron largely below the root zone of herbaceous plants and vines, where it was available for uptake primarily by deeper-rooting trees.

High rates of tebuthiuron (>1.0 kg a.i./ha) application resulted in temporary forb depression and herbaceous species richness reductions in previous studies (Scifres and Mutz 1978, Pettit 1979, Doerr and Guthery 1983, Guthery et al. 1987). In this study, forb densities and herbaceous richness increased on both ROWs following treatment ($P < 0.001$). However, forb biomass was lower post-treatment ($P < 0.001$). This may have resulted from older, tebuthiuron-killed perennial forbs being replaced by new plants. The study area showed increased density and coverage by grasses and

sedges, a response characteristic of tebuthiuron-treated sites (Pettit 1979, Doerr and Guthery 1983, Guthery et al. 1987, Defazio et al. 1988*a*, Fulbright and Garza 1991, Thompson et al. 1991).

Effects on Wildlife Habitat

It is difficult to determine the effects of tebuthiuron on individual plant species in field conditions, particularly because of interspecific competition, population dynamics, and site factors (Defazio et al. 1988*a*, Thompson et al. 1991). However, the sample size and sampling scheme in this study provided a reasonable basis for inferring tebuthiuron's influence on the most dominant plants in a mixed stand of trees, shrubs, vines, and herbaceous plants, particularly because the same transects and similar quadrat microsites were inventoried across years. Measures of vertical cover, ground cover, and species dominance before and after tebuthiuron treatment are probably sufficient for assessing pre- and post-treatment habitat quality based on previous food habits and habitat use research (Thompson et al. 1991, Guthery et al. 1987).

White-tailed Deer

White-tailed deer are generalist browsers capable of using a wide variety of foods (Atwood 1941, Harlow and Hooper 1971, Crawford 1984, Halls 1984). One deer habitat management strategy in the East is to encourage plant diversity and allow deer to select forages based on preference or nutritional needs (Weckerly 1988, Kennedy et al. 1991). Tebuthiuron appeared to have mixed effects on plant diversity,

with trees and shrubs declining in dominance and herbaceous plants increasing. Dominance among low-growing flora varied by species and year on ROWs. The increased species richness, ground cover, and biomass among herbaceous plants and vines coupled with the persistence of some preferred herbaceous foods such as lespedezas and honeysuckle post-treatment probably improved deer habitat within the context of the largely forested Oak Ridge Forest (Crawford 1984, Weckerly 1988, Kennedy et al. 1991).

Tree and shrub browse availability was significantly reduced after treatment (Table 17). Deer eat sumac bark, twigs, and fruit in fall and winter, though they are not preferred foods (Martin et al. 1951, Sossaman and Weber 1953, Burns and Honkala 1990). The reduction of sumacs in light of other available browse on both ROWs would probably only be detrimental for deer in the event of severe winter weather or in years of mast failure. Blackberries are important for food and cover for deer in the Southeast; their fruit and leaves are highly utilized by deer in fall and winter (Schopmeyer 1948, Halls and Ripley 1961, Lay 1965). The decrease in blackberry density and dominance on both ROWs would probably be a net negative effect for deer. Young red maple stems are preferred fall and winter browse for white-tails (Dahlberg and Guettinger 1956, Halls and Ripley 1961). Although red maple density decreased after treatment, frequency of occurrence did not significantly decrease. Also, red maple stems were shorter and potentially younger, on average, making them more available (compared to pre-treatment) and possibly more nutritious (Weckerly 1988).

Table 17. Effects of tebuthiuron treatment on major vegetation variables and white-tailed deer habitat on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]		Citations
		Food	Cover	
Blackberries	Decreased density/dominance	-1	-1	Harlow et al. 1974, Kennedy et al. 1991
Sumacs	Decreased density/dominance	-1	-1	Lay 1965, Kennedy et al. 1991
Red Maple	Decreased density/dominance	-1	-1	Dahlberg and Guettinger 1956
Wild Black Cherry	Decreased density/dominance	-1	-1	Webb 1959
Shagbark Hickory	Decreased density/dominance	-1	-1	Harlow and Hooper 1971
Black Gum	Decreased density/dominance	-1	-1	Lay 1965, Kennedy et al. 1991
Japanese Honeysuckle	None	0	0	
Goldenrod	None	0	0	
Tick Trefoil	Decreased dominance	-1	-1	Adams 1959, Kennedy et al. 1991
Broomsedge	Increased dominance	+1	+1	Sossaman et al. 1973, Kennedy et al. 1991
Snakeroot	Increased dominance	?	+1	Kennedy et al. 1991, Crawford 1984
Partridge-Pea	Decreased dominance	-1	-1	Harlow and Hooper 1971, Crawford 1984
Greenbrier	None	0	0	
Panic Grasses	Decreased dominance	-1	-1	Sossaman et al. 1973, Kennedy et al. 1991
Sedges	None	0	0	
Hairy Bush-Clover	Increased dominance	+1	+1	Adams 1959, Crawford 1984
Asters	Decreased dominance	-1	-1	Martin et al 1951, Kennedy et al. 1991
Milk Pea	Increased dominance	+1	+1	Harlow and Hooper 1971, Crawford 1984
Wintercress	Increased dominance	?	0	
Barren Strawberry	Decreased dominance	?	0	
Vertical Cover	Decreased	-1	-1	Crawford 1984, Kennedy et al. 1991
Ground Cover	Increased	+1	+1	Crawford 1984, Weckerly 1988

[a]The effects of tebuthiuron on white-tailed deer habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

Vertical cover reductions may discourage deer use of the formerly brushy ROWs following tebuthiuron treatment (Tanner et al. 1978), though low human disturbance and the proximity to adjacent forest cover on the Oak Ridge Forest probably minimize this drawback. Openings with abundant grasses and forbs have been shown to increase deer use of forests (McCaffrey and Creed 1969, Crawford 1984). Because the Oak Ridge Forest is largely covered with mature forest, changes resulting from tebuthiuron treatment on ROWs probably were positive overall. Also, reductions in vertical cover are probably temporary, because seedlings and sucker sprouts will eventually repopulate the ROWs with trees and shrubs.

Small Mammals

White-footed mice and meadow voles probably benefit from increased density and biomass of grasses and forbs following tebuthiuron treatment (Getz 1961, King 1968, Godin 1977, Hamilton and Whitaker 1979, Linzey and Cranford 1984). The decline of trees such as black gum and wild black cherry represent potential losses of minor food sources and cover from aerial predators (Table 18) (Martin et al. 1951, Mersmann and Fraser 1990). Meadow vole density may increase with increased grass biomass, though, so post-treatment increases in grass weight and herbaceous ground cover should compensate by increasing food availability (Steele 1977). Increases in ground cover post-treatment should improve escape, thermal, hiding, and nesting cover for white-footed mice as well (Godin 1977, Hamilton and Whitaker 1979). Because herbaceous cover types are not well-represented on the Oak Ridge Forest, and because forest is adjacent to ROWs, vegetation changes on the utility corridor were

Table 18. Effects of tebuthiuron treatment on major vegetation variables and white-footed mouse and meadow vole habitat on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

		Habitat Effects[a]			
			Cover		
Vegetation Variable	Major Treatment Effects	Food	Mouse	Vole	Citations
Blackberries	Decreased density/dominance	-1	0[b]	+1	Hamilton 1941, Getz 1961 Linzey and Cranford 1984
Sumacs	Decreased density/dominance	0	0	+1	Getz 1961, Linzey and Cranford 1984
Red Maple	Decreased density/dominance	0	0	+1	Getz 1961, Linzey and Cranford 1984
Wild Black Cherry	Decreased density/dominance	-1	0	+1	Hamilton 1941, Getz 1961 Linzey and Cranford 1984
Shagbark Hickory	Decreased density/dominance	-1	0	+1	Getz 1961, Linzey and Cranford 1984
Black Gum	Decreased density/dominance	0	0	+1	Getz 1961, Linzey and Cranford 1984
Japanese Honeysuckle	None	0	0	0	
Goldenrod	None	0	0	0	
Tick Trefoil	Decreased dominance	-1	-1	-1	Martin et al. 1951, Getz 1961
Broomsedge	Increased dominance	+1	+1	+1	Getz 1961, Linzey and Cranford 1984
Snakeroot	Increased dominance	0	+1	+1	Martin et al. 1951, Getz 1961
Partridge-Pea	Decreased dominance	0	-1	-1	Martin et al. 1951, Getz 1961
Greenbrier	None	0	0	0	
Panic Grasses	Decreased dominance	0	-1	-1	Getz 1961, Linzey and Cranford 1984
Sedges	None	0	0	0	
Hairy Bush-Clover	Increased dominance	+1	+1	+1	Martin et al. 1951, Getz 1961 Lindroth and Batzli 1984
Asters	Decreased dominance	-1	-1	-1	Martin et al. 1951, Getz 1961, Bucyanayandi and Bergeron 1990
Milk Pea	Increased dominance	0	+1	+1	Martin et al. 1951, Getz 1961
Wintercress	Increased dominance	0	+1	+1	Martin et al. 1951, Getz 1961
Barren Strawberry	Decreased dominance	-1	-1	-1	Martin et al. 1951, Getz 1961
Vertical Cover	Decreased	0	-1	0	Martin et al. 1951, Getz 1961
Ground Cover	Increased	+1	+1	+1	Martin et al. 1951, Getz 1961

[a]The effects of tebuthiuron on small mammal habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

[b]Tree canopy removal increases detection by raptors.

probably positive for these small mammals (Godin 1977, Martin et al. 1951, Hamilton and Whitaker 1979).

Wild Turkey

Although extensively cleared land is poor-quality habitat for wild turkey, the species heavily utilizes herbaceous forest-openings and edges for foraging on plants and invertebrates year-round and for nesting (Glover 1949*b*, Holbrook 1973, Schroeder 1985*a*, Hurst 1992, Porter 1992). Tebuthiuron treatment released broadleaf herbaceous weeds and grasses from tree competition, allowing them to increase in dominance and in availability for turkey foraging and nest location (Table 19). One estimate of ideal herbaceous plant dry weight for southeastern brood habitat was 600 to 3,000 kg/ha (Healy 1978). Herbaceous plant biomass on both ROWs rose to within this range both years following treatment (Table 15).

Dominance decreased following tebuthiuron treatment for some tree and shrub species that provide fruits important to wild turkeys, including blackberries, dogwood, wild black cherry, and black gum (Hurst 1992, Glover 1949*b*). Mature individuals of these tree and shrub species occur in adjacent forested areas, so their reductions should be unimportant on the landscape scale. Changes in dominant herbaceous foods appeared to be neutral (Table 19), but post-treatment increases in ground cover undoubtedly would attract more invertebrates (Healy 1981, Dickson 1992, Hurst 1992).

Although the overall shift in vegetation dominance from woody brush to herbaceous plants is advantageous for wild turkey brood-rearing, 1 concern about

Table 19. Effects of tebuthiuron treatment on major vegetation variables and wild turkey habitat on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]				Citations
			Cover			
		Food	Nesting	Escape	Brood	
Blackberries	Decreased density/dominance	-1	0[b]	-1	+1	Glover 1949, Hurst 1992, Everett et al. 1981, Healy 1981 Schroeder 1985*a*
Sumacs	Decreased density/dominance	-1	0	-1	+1	Everett et al. 1981, Healy 1981, Schroeder 1985*a*, Hurst 1992, Hurst and Dickson 1992
Red Maple	Decreased density/dominance	0	0	-1	+1	Martin et al. 1951, Everett et al. 1981, Healy 1981, Schroeder 1985*a*, Hurst and Dickson 1992
Wild Black Cherry	Decreased density/dominance	-1	0	-1	+1	Glover 1949, Everett et al. 1981, Schroeder 1985*a*,
Shagbark Hickory	Decreased density/dominance	0	0	-1	+1	Martin et al. 1951, Everett et al. 1981, Healy 1981, Schroeder 1985*a*, Hurst and Dickson 1992
Black Gum	Decreased density/dominance	-1	0	-1	+1	Martin et al. 1951, Everett et al. 1981, Schroeder 1985*a*, Porter 1992
Japanese Honeysuckle	None	0	0	0	0	
Goldenrod	None	0	0	0	0	
Tick Trefoil	Decreased dominance	-1	-1	0	-1	Martin et al. 1951, Everett et al. 1981, Schroeder 1985*a*
Broomsedge	Increased dominance	+1	+1	0	+1	Martin et al. 1951, Williams 1981, Hurst and Dickson 1992

Table 19. (continued)

Vegetation Variable	Major Treatment Effects	Habitat Effects				Citations
			Cover			
		Food	Nesting	Escape	Brood	
Snakeroot	Increased dominance	+1	+1	0	+1	Hurst and Dickson 1992, Porter 1992
Partridge-Pea	Decreased dominance	-1	-1	0	-1	Hurst and Dickson 1992, Porter 1992
Greenbrier	None	0	0	0	0	
Panic Grasses	Decreased dominance	-1	-1	0	-1	Glover 1949, Korschgen 1967, Healy 1981, Williams 1981
Sedges	None	0	0	0	0	
Hairy Bush-Clover	Increased dominance	+1	+1	0	+1	Martin et al. 1951, Hurst and Dickson 1992, Porter 1992
Asters	Decreased dominance	-1	-1	0	-1	Martin et al. 1951, Hurst and Dickson 1992, Porter 1992
Milk Pea	Increased dominance	+1	+1	0	+1	Martin et al. 1951, Hurst and Dickson 1992, Porter 1992
Wintercress	Increased dominance	+1	+1	0	+1	Martin et al. 1951, Hurst and Dickson 1992, Porter 1992
Barren Strawberry	Decreased dominance	-1	-1	0	-1	Martin et al. 1951, Hurst and Dickson 1992
Vertical Cover	Decreased	0	-1	-1	+1	Hurst and Dickson 1992, Porter 1992
Ground Cover	Increased	+1	+1	0	+1	Healy 1981, Hurst 1992, Hurst and Dickson 1992

[a]The effects of tebuthiuron on wild turkey habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

[b]Wild turkeys nest in forests, forest edges, and openings with ample low cover.

post-treatment turkey habitat on ROWs is the thickness and height of herbaceous cover 2-years post-treatment in some areas on the corridor (Figure 5). Because hens rely heavily on vision for detection of and escape from predators, suitability of the habitat could be reduced compared to a herbaceous cover maintained at a lower height (Schroeder 1985*a*, Dickson 1992). Another concern about tebuthiuron's effects on turkey habitat on the corridor is the reduction in escape cover provided by trees before treatment. However, Oak Ridge Forest provides sizeable oak-hickory stands adjacent to the powerline corridor for escape cover and other life-history requirements, including roosting cover. Turkeys nest in a variety of open, edge, or forested settings, so pre- and post-treatment conditions were probably suitable nesting habitat (Hurst and Dickson 1992).

Few herbaceous-dominated areas occur on the Oak Ridge Forest. Thus, the net effects of tebuthiuron treatment on ROW vegetation should be beneficial for wild turkeys, especially for poult-rearing, when seed and invertebrate supplies are critical (Healy 1978, Hurst 1992, Porter 1992).

Ruffed Grouse

Ruffed grouse depend on forested areas with mature trees, and brush- or shrub- covered areas; forest openings like ROWs, with early seral stage vegetation, are used for spring-fall foraging when forbs and fruits are abundant (Bump et al. 1947, Cade and Sousa 1985, Barber et al. 1989*a*, Barber et al. 1989*b*). Ruffed grouse foods represented by trees on ROWs include sumac berries, black cherry buds and fruits, and red maple seeds and buds (Martin et al. 1951, Cade and Sousa 1985, Barber et al.

1989*a*), though buds comprise a relatively small portion of grouse diets in the Ridge and Valley (Stafford 1975, Stafford and Dimmick 1979). The decrease in density and dominance of these foods represent a negative effect on emergency winter ruffed grouse foods; reductions in tree and shrub cover would also be detrimental to grouse foraging habitat (Table 20) (Bump et al. 1947, White and Dimmick 1978, Cade and Sousa 1985). However, some important eastern Tennessee grouse foods remained or increased on ROWs following treatment, including Japanese honeysuckle, greenbrier, sedges, and some forbs (Hungerford 1957, Stafford and Dimmick 1979, Longwitz 1985). Because herbaceous plants and vines are particularly important to southeastern ruffed grouse (Stafford and Dimmick 1979), and because tree cover was available adjacent to the corridor, the ROWs were still undoubtedly usable for foraging by ruffed grouse, particularly along ROW edges (Bump et al. 1947; Barber et al. 1989*b*; R. W. Dimmick, Univ. Tenn., Knoxville, pers. commun.).

Ruffed grouse nest in wooded or brushy habitats with open understories since hens must visually monitor their environs for predators (Bump et al. 1947, Cade and Sousa 1985, Barber et al. 1989*a*). Before treatment, ROWs had greater tree canopy cover, higher woody stem densities, and less understory development compared to conditions after treatment; changes were negative for nesting ruffed grouse (Bump et al. 1947, Berner and Gysel 1969, Kubisiak 1978, Cade and Sousa 1985). Trees and shrubs are also relied on heavily by ruffed grouse for escape from predators (Bump et al. 1947, White and Dimmick 1978, Cade and Sousa 1985). Ruffed grouse escape

Table 20. Effects of tebuthiuron treatment on major vegetation variables and ruffed grouse habitat on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]				Citations
			Cover[b]			
		Food	Nesting	Escape	Brood	
Blackberries	Decreased density/dominance	-1	-1	-1	-1	Hungerford 1957, Rusch and Keith 1971, Barber et al. 1989*b*
Sumacs	Decreased density/dominance	-1	-1	-1	-1	Brown 1946, Gullion 1970, Barber et al. 1989*b*
Red Maple	Decreased density/dominance	0	-1	-1	-1	Martin et al. 1951, Gullion 1970, Barber et al. 1989*b*
Wild Black Cherry	Decreased density/dominance	-1	-1	-1	-1	Martin et al. 1951, Gullion 1970, Cade and Sousa 1985
Shagbark Hickory	Decreased density/dominance	0	-1	-1	-1	Martin et al. 1951, Gullion 1970, Barber et al. 1989*b*
Black Gum	Decreased density/dominance	0	-1	-1	-1	Martin et al. 1951, Gullion 1970, Barber et al. 1989*b*
Japanese Honeysuckle	None	0	0	0	0	
Goldenrod	None	0	0	0	0	
Tick Trefoil	Decreased dominance	-1	-1	0	+1	Martin et al. 1951, Barber et al. 1989*b*
Broomsedge	Increased dominance	0	-1[c]	0	-1	Martin et al. 1951, Palmer 1963, Cade and Sousa 1985
Snakeroot	Increased dominance	0	-1	0	+1	Martin et al. 1951, Palmer 1963, Cade and Sousa 1985
Partridge-Pea	Decreased dominance	0	+1	0	-1	Martin et al. 1951, Palmer 1963, Cade and Sousa 1985
Greenbrier	None	0	0	0	0	
Panic Grasses	Decreased dominance	0	+1	0	+1	Martin et al. 1951, Hungerford 1957, Gullion 1970
Sedges	None	0	0	0	0	
Hairy Bush-Clover	Increased dominance	+1	-1	0	+1	Martin et al. 1951, Longwitz 1985, Barber et al. 1989*b*

Table 20. (continued)

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]				Citations
			Cover[b]			
		Food	Nesting	Escape	Brood	
Asters	Decreased dominance	-1	-1	0	-1	Stafford and Dimmick 1979, Norman and Kirkpatrick 1984, Barber et al. 1989*b*
Milk Pea	Increased dominance	+1	0	0	+1	Martin et al. 1951, Barber et al. 1989*b*
Wintercress	Increased dominance	?	0	0	0	Martin et al. 1951, Gullion 1970
Barren Strawberry	Decreased dominance	-1	0	0	0	Martin et al. 1951, Barber et al. 1989*b*
Vertical Cover	Decreased	0	-1	-1	-1	Gullion 1977, White and Dimmick 1978, Barber et al. 1989*b*
Ground Cover	Increased	+1	+1	0	+1	Maxson 1978, Cade and Sousa 1985, Hollifield 1992

[a]The effects of tebuthiuron on ruffed grouse habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

[b]Tree canopy removal increases likelihood of predation by raptors.

[c]Dense bunchgrasses impede vision of hens and mobility of chicks.

cover on ROWs probably decreased in suitability after tebuthiuron treatment, although forest cover was available nearby.

Ruffed grouse broods forage in forests and openings with well developed herbaceous growth, though extremely high densities of grasses, sedges, or forbs hinder chick mobility and, thus, foraging capability (Bump et al. 1947, Cade and Sousa 1985, Barber et al. 1989*a*). Brood habitat on ROWs before tebuthiuron treatment offered a dense tree and shrub canopy and a high percentage of vertical cover to protect chicks from predation (Cade and Sousa 1985, Barber et al. 1989*a*); these cover sources were reduced after treatment. Forbs provide fruits, seeds and leaves, and attract insects needed for food by grouse chicks (Stafford and Dimmick 1979, Barber et al. 1989*a*, Hollifield 1992). Forb biomass decreased but forb density increased post-treatment (Tables 10 and 15). Ground cover greatly increased following treatment, but no research has identified a high percentage of herbaceous ground cover as a brood habitat requirement. Overall, brood habitat quality strictly on the ROWs probably decreased following tebuthiuron treatment because of reductions in tree canopy cover and vertical cover. However, since untreated buffer strips were left on ROW edges, and since forb densities increased, ruffed grouse broods may have been provided with suitable habitat in the transition zones between ROWs and adjacent forested areas.

Northern Bobwhite

Northern bobwhite food plants exhibited a mixed response to tebuthiuron treatment. Blackberries (Dimmick 1992), sumacs (Eubanks and Dimmick 1974), partridge-pea (Eubanks and Dimmick 1974), panic grass (Eubanks and Dimmick 1974), and tick-trefoils (Rosene and Freeman 1988) were bobwhite foods that decreased in dominance on ROWs after treatment. Japanese honeysuckle (Landers and Johnson 1976), sedges (Eubanks and Dimmick 1974), hairy bush-clover (Rosene and Freeman 1988), wintercress (Landers and Johnson 1976), and milk pea (Landers and Johnson 1976) are bobwhite foods that either remained dominant or increased in dominance 1- or 2-years post-treatment.

Cover on ROWs 1-2 years post-treatment was nearly ideal for bobwhite foraging and nesting (Table 21) (Rosene 1969, Dimmick 1971, Schroeder 1985*b*). ROWs were dominated by broomsedge and other herbaceous vegetation, they had some bare ground between plants to aid in seed location by quail, and they afforded a combination of seed-bearing plants and lush forbs that attract insects (Rosene 1969, Schroeder 1985*b*, Dimmick 1992). Although trees were reduced on both ROWs, adjacent forest probably provided ample escape cover for quail foraging in the corridor. By fall of 1994, however, broomsedge and other grass bunches were so thick in some areas on ROWs that nesting or foraging and movement by quail could have been hindered (Martin et al. 1951, Rosene 1969, Schroeder 1985*b*, Dimmick 1992). Thick, post-treatment herbaceous vegetation could be made more suitable for bobwhite nesting through discing or controlled burning (Dimmick 1971; R. W. Dimmick, Univ.

Table 21. Effects of tebuthiuron treatment on major vegetation variables and northern bobwhite habitat on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]				Citations
			Cover			
		Food	Nesting	Escape	Brood	
Blackberries	Decreased density/dominance	-1	-1	-1[b]	0	Rosene 1969, Eubanks and Dimmick 1974 Klimstra and Roseberry 1975, Dimmick 1992
Sumacs	Decreased density/dominance	-1	+1	-1	0	Korschgen 1948, Rosene and Freeman 1988, Dimmick 1992
Red Maple	Decreased density/dominance	0	+1	-1	0	Martin et al. 1951, Rosene and Freeman 1988, Dimmick 1992
Wild Black Cherry	Decreased density/dominance	-1	+1	-1	0	Eubanks and Dimmick 1974, Dimmick 1992
Shagbark Hickory	Decreased density/dominance	0	+1	-1	0	Martin et al. 1951, Rosene and Freeman 1988, Dimmick 1992
Black Gum	Decreased density/dominance	0	+1	-1	0	Baldwin and Handley 1946, Rosene and Freeman 1988, Dimmick 1992
Japanese Honeysuckle	None	0	0	0	0	
Goldenrod	None	0	0	0	0	
Tick Trefoil	Decreased dominance	-1	-1	0	-1	Korschgen 1948, Dimmick 1992
Broomsedge	Increased dominance	+1	+1	0	-1[c]	Martin et al. 1951, Shroeder 1985*b*, Dimmick 1992
Snakeroot	Increased dominance	0	?	0	+1	Martin et al. 1951, Rosene and Freeman 1988
Partridge-Pea	Decreased dominance	-1	+1	0	-1	Baldwin and Handley 1946, Dimmick 1971, Dimmick 1992
Greenbrier	None	0	0	0	0	
Panic Grasses	Decreased dominance	-1	-1	0	+1	Eubanks and Dimmick 1974, Dimmick 1992

Table 21. (continued)

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]				Citations
			Cover			
		Food	Nesting	Escape	Brood	
Sedges	None	0	0	0	0	
Hairy Bush-Clover	Increased dominance	+1	+1	0	+1	Baldwin and Handley 1946, Korschgen 1948, Dimmick 1992
Asters	Decreased dominance	0	?	0	-1	Martin et al. 1951, Rosene and Freeman 1988
Milk Pea	Increased dominance	+1	+1	0	+1	Korschgen 1948, Davison 1958
Wintercress	Increased dominance	+1	?	0	+1	Martin et al. 1951, Rosene and Freeman 1988
Barren Strawberry	Decreased dominance	-1	?	0	-1	Martin et al. 1951, Rosene and Freeman 1988
Vertical Cover	Decreased	0	-1[d]	-1	-1	Rosene 1969, Schroeder 1985*b*
Ground Cover	Increased	+1	+1	0	+1	Rosene 1969, Shroeder 1985*b*

[a]The effects of tebuthiuron on northern bobwhite habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

[b]Tree canopy removal increases likelihood of predation by raptors.

[c]Dense bunchgrasses impede mobility of chicks.

[d]Reduced vertical cover increases likelihood of predation.

Tenn., Knoxville, pers. commun.). Given the lack of forest openings on the Oak Ridge Forest, the herbaceous plant community changes resulting from tebuthiuron treatment probably increased the Forest's carrying capacity for bobwhites.

Eastern Cottontail

Eastern cottontail food habits vary by region and forage availability (Allen 1984), but the species will consume almost any grass, sedge, forb, or woody plant (Sweetman 1944, Dusi 1952, Allen 1984). Food availability and cover quality are probably the most critical habitat management concerns for the species (Dalke and Sime 1941, Allen 1984). Food (Table 15) and cover (Tables 6 and 10) were probably available in sufficient amounts on both ROWs for cottontail use pre- and post-treatment. Before treatment, cottontails could have used blackberry thickets and patchy bicolor lespedeza for thermal, escape, and hiding cover (Allen 1984). Post-treatment, cover needs could be met with dense broomsedge, willow grass, and other herbaceous plants, although tree canopy removal (Table 22) may have made rabbits more susceptible to raptor predation (Trent and Rongstad 1974). Post-treatment habitat dominated by herbaceous plants and shrubs is probably preferred by rabbits for foraging over tree- and shrub- dominated pretreatment habitat because of better nutrition (Sweetman 1944, Shoemaker 1979, Holloran et al. 1981, Allen 1984). As with turkey, deer, and northern bobwhites, the grass and forb cover increases resulting from tebuthiuron treatment were probably beneficial overall for cottontails on the Oak Ridge Forest because of the limited area maintained in this cover type.

Table 22. Effects of tebuthiuron treatment on major vegetation variables and eastern cottontail habitat on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]		Citation
		Food	Cover	
Blackberries	Decreased density/dominance	-1	-1[b]	Dalke and Sime 1941, Martin et al. 1951, Allen 1984
Sumacs	Decreased density/dominance	-1	-1	Martin et al. 1951, Allen 1984
Red Maple	Decreased density/dominance	-1	-1	Dalke and Sime 1941, Martin et al. 1951
Wild Black Cherry	Decreased density/dominance	-1	-1	Dalke and Sime 1941, Martin et al. 1951
Shagbark Hickory	Decreased density/dominance	-1	-1	Dalke and Sime 1941, Allen 1984
Black Gum	Decreased density/dominance	0	-1	Martin et al. 1951, Allen 1984
Japanese Honeysuckle	None	0	0	Martin et al. 1951, Allen 1984
Goldenrod	None	0	0	Dalke and Sime 1941, Allen 1984
Tick Trefoil	Decreased dominance	0	-1	Dalke and Sime 1941
Broomsedge	Increased dominance	+1	0	Martin et al. 1951, Allen 1984
Snakeroot	Increased dominance	0	+1	Martin et al. 1951, Allen 1984
Partridge-Pea	Decreased dominance	0	-1	Martin et al. 1951, Allen 1984
Greenbrier	None	0	0	Dalke and Sime 1941
Panic Grasses	Decreased dominance	-1	-1	Dalke and Sime 1941, Allen 1984
Sedges	None	0	0	Dalke and Sime 1941, Allen 1984
Hairy Bush-Clover	Increased dominance	?	+1	Dalke and Sime 1941, Allen 1984
Asters	Decreased dominance	-1	-1	Dalke and Sime 1941, Allen 1984
Milk Pea	Increased dominance	?	+1	Martin et al. 1951, Allen 1984
Wintercress	Increased dominance	?	+1	Martin et al. 1951, Allen 1984
Barren Strawberry	Decreased dominance	+1	0	Martin et al. 1951, Allen 1984
Vertical Cover	Decreased	0	-1[c]	Allen 1984
Ground Cover	Increased	+1	+1	Allen 1984

[a]The effects of tebuthiuron on eastern cottontail habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

[b]Tree canopy removal increases detection by raptors.

[c]Reduced vertical cover increases detectability by scansorial predators.

Songbirds

The quality of songbird habitat pre- and post-treatment would depend on the species under consideration and its life-history requirements. Foraging and nesting habitat are important determinants of habitat quality (D. A. Buehler, Univ. Tenn., Knoxville, pers. commun.). I will focus on foraging and nesting habitat requirements for 3 representative songbird species: grasshopper sparrow, prairie warbler, and wood thrush. These species utilize very different habitats; effects of tebuthiuron on ROW vegetation would thus affect them differently.

The grasshopper sparrow is a ground-nester that forages on insects and seeds in grass-dominated stands (~ 0.3 m tall) (Hamel 1992). Stand conditions on ROWs during 1993 or 1994, when vines, grasses and sedges, and forbs replaced trees as the most dominant species groups, more closely matched suitable habitat for grasshopper sparrows than pretreatment habitat (Hamel 1992). For grasshopper sparrows and other grassland birds, tebuthiuron-induced habitat changes were undoubtedly beneficial (Table 23).

Prairie warblers require sapling or shrub cover for breeding habitat (Hamel 1992). These birds glean insects and other small invertebrates from leaves and twigs of trees 0.3-3 m off the ground (Hamel 1992). Prairie warbler habitat quality was probably adversely affected by tebuthiuron treatment because of reductions in tree and shrub densities, average heights, and frequencies of occurrence (Table 24). Except for a few small, regenerating clearcuts and tornado-damaged areas, the Oak Ridge Forest

Table 23. Effects of tebuthiuron treatment on major vegetation variables and grasshopper sparrow habitat on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]		Citations
		Food	Cover	
Blackberries	Decreased density/dominance	+1	+1	Martin et al. 1951, Hamel 1992
Sumacs	Decreased density/dominance	+1	+1	Martin et al. 1951, Hamel 1992
Red Maple	Decreased density/dominance	+1	+1	Martin et al. 1951, Hamel 1992
Wild Black Cherry	Decreased density/dominance	+1	+1	Martin et al. 1951, Hamel 1992
Shagbark Hickory	Decreased density/dominance	+1	+1	Martin et al. 1951, Hamel 1992
Black Gum	Decreased density/dominance	+1	+1	Martin et al. 1951, Hamel 1992
Japanese Honeysuckle	None	0	0	Martin et al. 1951, Hamel 1992
Goldenrod	None	0	0	Martin et al. 1951, Hamel 1992
Tick Trefoil	Decreased dominance	-1	-1	Martin et al. 1951, Hamel 1992
Broomsedge	Increased dominance	+1	+1	Martin et al. 1951, Hamel 1992
Snakeroot	Increased dominance	+1	+1	Martin et al. 1951, Hamel 1992
Partridge-Pea	Decreased dominance	0	0	Martin et al. 1951, Hamel 1992
Greenbrier	None	0	0	Martin et al. 1951, Hamel 1992
Panic Grasses	Decreased dominance	-1	-1	Martin et al. 1951, Hamel 1992
Sedges	None	0	0[b]	Martin et al. 1951, Hamel 1992
Hairy Bush-Clover	Increased dominance	+1	+1	Martin et al. 1951, Hamel 1992
Asters	Decreased dominance	-1	-1	Martin et al. 1951, Hamel 1992
Milk Pea	Increased dominance	+1	+1	Martin et al. 1951, Hamel 1992
Wintercress	Increased dominance	+1	+1	Martin et al. 1951, Hamel 1992
Barren Strawberry	Decreased dominance	-1	-1	Martin et al. 1951, Hamel 1992
Vertical Cover	Decreased	+1	+1	Hamel 1992
Ground Cover	Increased	+1	+1	Hamel 1992

[a]The effects of tebuthiuron on grasshopper sparrow habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

[b]Grasshopper sparrows forage primarily on invertebrates. Sedges are the only dominant plants on rights-of-way listed as a food source by Martin et al. 1951.

Table 24. Effects of tebuthiuron treatment on major vegetation variables and prairie warbler habitat on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]		Citations
		Food	Cover	
Blackberries	Decreased density/dominance	-1	-1[b]	Martin et al. 1951, Hamel 1992
Sumacs	Decreased density/dominance	-1	-1	Martin et al. 1951, Hamel 1992
Red Maple	Decreased density/dominance	-1	-1	Martin et al. 1951, Hamel 1992
Wild Black Cherry	Decreased density/dominance	-1	-1	Martin et al. 1951, Hamel 1992
Shagbark Hickory	Decreased density/dominance	-1	-1	Martin et al. 1951, Hamel 1992
Black Gum	Decreased density/dominance	-1	-1	Martin et al. 1951, Hamel 1992
Japanese Honeysuckle	None	0	0	Martin et al. 1951, Hamel 1992
Goldenrod	None	0	0	Martin et al. 1951, Hamel 1992
Tick Trefoil	Decreased dominance	0	0	Martin et al. 1951, Hamel 1992
Broomsedge	Increased dominance	0	0	Martin et al. 1951, Hamel 1992
Snakeroot	Increased dominance	0	0	Martin et al. 1951, Hamel 1992
Partridge-Pea	Decreased dominance	0	0	Martin et al. 1951, Hamel 1992
Greenbrier	None	0	0	Martin et al. 1951, Hamel 1992
Panic Grasses	Decreased dominance	0	0	Martin et al. 1951, Hamel 1992
Sedges	None	0	0	Martin et al. 1951, Hamel 1992
Hairy Bush-Clover	Increased dominance	0	0	Martin et al. 1951, Hamel 1992
Asters	Decreased dominance	0	0	Martin et al. 1951, Hamel 1992
Milk Pea	Increased dominance	0	0	Martin et al. 1951, Hamel 1992
Wintercress	Increased dominance	0	0	Martin et al. 1951, Hamel 1992
Barren Strawberry	Decreased dominance	0	0	Martin et al. 1951, Hamel 1992
Vertical Cover	Decreased	-1	-1	Hamel 1992
Ground Cover	Increased	0	0	Hamel 1992

[a]The effects of tebuthiuron on prairie warbler habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

[b]Prairie warblers nest and forage in sapling-shrub cover.

lacks large tracts of brushy habitat. Tebuthiuron-induced changes in prairie warbler habitat were probably detrimental (D. A. Buehler, Univ. Tenn., Knoxville, pers. commun.).

The wood thrush primarily inhabits deciduous or mixed forests with fairly well-developed deciduous understories; it feeds by gleaning insects from the forest floor and off shrubs and understory trees (Hamel 1992). Wood thrush prefer mesic hardwood-dominated forests, but may also frequent white pine (*P. strobus*)-eastern hemlock (*Tsuga canadensis*) forests with ample understory growth (Hamel 1992).

Wood thrush probably do not use areas like ROWs. A possible exception may be where brush is very tall and understory vegetation is well-developed, as was the case on ROW 2 in 1992. Potential use of ROWs on Oak Ridge Forest by wood thrushes was probably minimal pretreatment in lieu of alternative forested habitat, but tebuthiuron's effect of removing the tree canopy from ROWs 1 and 2 probably altogether precluded the species' use of either ROW after treatment. Deciduous shrubs used for foraging decreased following treatment, and desirable leaf litter will be minimal in subsequent years because of the drastic reduction in deciduous trees (Table 25). Also, post-treatment ROW vegetation contrasts more with surrounding forest than the dense brush present before treatment. This increased contrast at the forest edge may be harmful to forest interior species like the wood thrush that are sensitive to habitat fragmentation and nest parasitism (Rich et al. 1994).

Table 25. Effects of tebuthiuron treatment on major vegetation variables and wood thrush on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]		Citations
		Food	Cover	
Blackberries	Decreased density/dominance	-1	-1[b]	Martin et al. 1951, Hamel 1992
Sumacs	Decreased density/dominance	-1	-1	Martin et al. 1951, Hamel 1992
Red Maple	Decreased density/dominance	-1	-1	Martin et al. 1951, Hamel 1992
Wild Black Cherry	Decreased density/dominance	-1	-1	Martin et al. 1951, Hamel 1992
Shagbark Hickory	Decreased density/dominance	-1	-1	Martin et al. 1951, Hamel 1992
Black Gum	Decreased density/dominance	-1	-1	Martin et al. 1951, Hamel 1992
Japanese Honeysuckle	None	0	0	Martin et al. 1951, Hamel 1992
Goldenrod	None	0	0	Martin et al. 1951, Hamel 1992
Tick Trefoil	Decreased dominance	+1	+1	Martin et al. 1951, Hamel 1992
Broomsedge	Increased dominance	-1	-1	Martin et al. 1951, Hamel 1992
Snakeroot	Increased dominance	-1	-1	Martin et al. 1951, Hamel 1992
Partridge-Pea	Decreased dominance	+1	+1	Martin et al. 1951, Hamel 1992
Greenbrier	None	0	0	Martin et al. 1951, Hamel 1992
Panic Grasses	Decreased dominance	+1	+1	Martin et al. 1951, Hamel 1992
Sedges	None	0	0	Martin et al. 1951, Hamel 1992
Hairy Bush-Clover	Increased dominance	-1	-1	Martin et al. 1951, Hamel 1992
Asters	Decreased dominance	-1	-1	Martin et al. 1951, Hamel 1992
Milk Pea	Increased dominance	-1	-1	Martin et al. 1951, Hamel 1992
Wintercress	Increased dominance	-1	-1	Martin et al. 1951, Hamel 1992
Barren Strawberry	Decreased dominance	+1	+1	Martin et al. 1951, Hamel 1992
Vertical Cover	Decreased	-1	-1	Hamel 1992
Ground Cover	Increased	-1	-1	Hamel 1992

[a]The effects of tebuthiuron on wood thrush habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

[b]Wood thrushes forage in leaf litter of moist, open tree understory.

Red-tailed Hawk

Red-tailed hawks primarily hunt pastures and fields with low herbaceous growth but also use old fields and woods less frequently (Sferra 1984). Red-tailed hawks prey on small mammals such as voles (*Microtus* spp.) and mice (*Peromyscus* spp.), squirrels (*Sciurus* spp.), cottontails, small songbirds and gamebirds, and snakes and lizards (May 1935, Fitch et al. 1946, Bond 1947, Heintzelman 1979). Optimal red-tail foraging habitat on ROWs would be herbaceous cover if prey abundance was also high (Sferra 1984, Mersmann and Fraser 1990). This habitat would afford the raptor relatively unobscured vision to identify and pursue prey. Although I did not monitor prey populations pre- and post-treatment, if prey populations were unchanged, the removal of the woody canopy should have greatly increased prey availability for red-tails (Table 26). Thus, red-tailed hawk habitat on both ROWs should have improved following tebuthiuron treatment.

Gray Fox

Gray foxes use mature woodland, shrubland, cultivated areas, brushy woodlands with sparse understories, and grassy old-field habitats for foraging (Trapp and Hallberg 1975, Yearsley and Samuel 1980, Haroldson and Fritzell 1984). Important foods include small mammals, cottontails, birds, eggs, insects, fruits, nuts, and grass (Nelson 1933, Errington 1935, Scott 1941, Glover 1949*a*, Martin et al. 1951, Yoho and Henry 1972, Hockman and Chapman 1983, Greenberg 1988). Grass, wild black cherry fruit, blackberry fruit, and grapes were the most frequent vegetarian foods consumed by gray foxes in 1 eastern Tennessee study (Greenberg 1988). Black cherry and blackberry

Table 26. Effects of tebuthiuron treatment on major vegetation variables and red-tailed hawk habitat on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]		Citation
		Food	Cover	
Blackberries	Decreased density/dominance	+1[b]	+1	Sferra 1984, Mersmann and Fraser 1990
Sumacs	Decreased density/dominance	+1	+1	Sferra 1984, Mersmann and Fraser 1990
Red Maple	Decreased density/dominance	+1	+1	Sferra 1984, Mersmann and Fraser 1990
Wild Black Cherry	Decreased density/dominance	+1	+1	Sferra 1984, Mersmann and Fraser 1990
Shagbark Hickory	Decreased density/dominance	+1	+1	Sferra 1984, Mersmann and Fraser 1990
Black Gum	Decreased density/dominance	+1	+1	Sferra 1984, Mersmann and Fraser 1990
Japanese Honeysuckle	None	0	0	Sferra 1984, Mersmann and Fraser 1990
Goldenrod	None	0	0	Sferra 1984, Mersmann and Fraser 1990
Tick Trefoil	Decreased dominance	-1[c]	0	Sferra 1984, Mersmann and Fraser 1990
Broomsedge	Increased dominance	+1	0	Sferra 1984, Mersmann and Fraser 1990
Snakeroot	Increased dominance	+1	0	Sferra 1984, Mersmann and Fraser 1990
Partridge-Pea	Decreased dominance	-1	0	Sferra 1984, Mersmann and Fraser 1990
Greenbrier	None	0	0	Sferra 1984, Mersmann and Fraser 1990
Panic Grasses	Decreased dominance	-1	0	Sferra 1984, Mersmann and Fraser 1990
Sedges	None	0	0	Sferra 1984, Mersmann and Fraser 1990
Hairy Bush-Clover	Increased dominance	+1	0	Sferra 1984, Mersmann and Fraser 1990
Asters	Decreased dominance	-1	0	Sferra 1984, Mersmann and Fraser 1990
Milk Pea	Increased dominance	+1	0	Sferra 1984, Mersmann and Fraser 1990
Wintercress	Increased dominance	+1	0	Sferra 1984, Mersmann and Fraser 1990
Barren Strawberry	Decreased dominance	-1	0	Sferra 1984, Mersmann and Fraser 1990
Vertical Cover	Decreased	0	+1	Sferra 1984, Mersmann and Fraser 1990
Ground Cover	Increased	+1	-1	Sferra 1984, Mersmann and Fraser 1990

[a]The effects of tebuthiuron on red-tailed hawk habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

[b]Decreases in trees and shrubs increase prey availability.

[c]Changes in herbaceous vegetation affect prey (small mammal) availability.

decreased on both ROWs after treatment in this study. These declines represent negative effects on fox habitat, though black cherry probably would not fruit during typical ROW management cycles. Grass, the most frequent vegetable food in gray fox stomachs in 1 eastern Tennessee study (Greenberg 1988), increased after tebuthiuron treatment. Grass increases plus improved habitat for small mammals on the corridor should increase food abundance for gray fox post-treatment (Table 27). The post-treatment shift away from tall, brushy cover to dense ground cover may discourage diurnal gray fox use of tebuthiuron-treated ROWs because in loss of cover (Haroldson and Fritzell 1984). However, the increase in herbaceous plant diversity and contrast between the ROWs and adjacent forests should be largely beneficial to the species, particularly since it forages largely at nocturnally (Yearsley and Samuel 1980).

Summary of Wildlife Habitat Changes

Following tebuthiuron treatment on the Oak Ridge Forest, habitat undoubtedly improved for white-tailed deer, white-footed mouse, meadow vole, wild turkey, northern bobwhite, eastern cottontails, grasshopper sparrow, red-tailed hawk, and gray fox. Decreases in trees and shrubs probably lowered habitat quality on the Oak Ridge Forest for ruffed grouse, prairie warbler, and wood thrush. Because most of the Forest's land area is occupied by forested or regenerating stands, tebuthiuron treatment diversified habitat by promoting density, cover, and richness increases in herbaceous plant communities. Although the powerline corridor makes up a relatively small percentage of the Oak Ridge Forest's land base, the vegetation changes therein represent significant improvements for species that use grasslands or forb cover.

Table 27. Effects of tebuthiuron treatment on major vegetation variables and gray fox habitat on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Vegetation Variable	Major Treatment Effects	Habitat Effects[a]		Citations
		Food	Cover	
Blackberries	Decreased density/dominance	-1	0	Greenberg 1988, Yearsley and Samuel 1980
Sumacs	Decreased density/dominance	-1	0	Martin et al. 1951, Greenberg 1988
Red Maple	Decreased density/dominance	0	0	Martin et al. 1951, Greenberg 1988
Wild Black Cherry	Decreased density/dominance	-1	0	Glover 1949, Scott 1955, Greenberg 1988
Shagbark Hickory	Decreased density/dominance	0	0	Martin et al. 1951, Greenberg 1988
Black Gum	Decreased density/dominance	-1	0	Martin et al. 1951, Greenberg 1988
Japanese Honeysuckle	None	0	0	
Goldenrod	None	0	0	
Tick Trefoil	Decreased dominance	0	-1	Martin et al. 1951, Greenberg 1988
Broomsedge	Increased dominance	+1	+1	Errington 1935, Greenberg 1988
Snakeroot	Increased dominance	0	+1	Martin et al. 1951, Greenberg 1988
Partridge-Pea	Decreased dominance	?	-1	Martin et al. 1951, Greenberg 1988
Greenbrier	None	0	0	
Panic Grasses	Decreased dominance	-1	-1	Errington 1935, Greenberg 1988
Sedges	None	0	0	
Hairy Bush-Clover	Increased dominance	?	+1	Martin et al. 1951, Greenberg 1988
Asters	Decreased dominance	0	-1	Martin et al. 1951, Greenberg 1988
Milk Pea	Increased dominance	?	+1	Martin et al. 1951, Greenberg 1988
Wintercress	Increased dominance	0	0	Martin et al. 1951, Greenberg 1988
Barren Strawberry	Decreased dominance	?	0	Martin et al. 1951, Greenberg 1988
Vertical Cover	Decreased	0	0[b]	Yearsley and Samuel 1980, Haroldson and Fritzell 1984, Greenberg 1988
Ground Cover	Increased	+1[c]	+1[c]	Haroldson and Fritzell 1984, Greenberg 1988

[a]The effects of tebuthiuron on gray fox habitat are evaluated as: +1 = positive effect, -1 = negative effect, 0 = no effect, and ? = unknown effect.

[b]Gray foxes use areas with tall cover for diurnal loafing but they forage in more open areas nocturnally or crepuscularly.

[c]Increased ground cover increases prey (small mammal) abundance and cover for diurnal loafing.

The habitat evaluation scheme used here (Tables 17-27) implies that vegetation variables used by a given wildlife species for food or cover are equally important. This assumption may not hold for some species because of differential use of habitat components daily, seasonally, or in relation to abundance (Robinson and Bolen 1989). Managers should modify this evaluation scheme based on the relative importance of vegetation variables for specific management areas and wildlife species to predict effects of tebuthiuron on habitat.

PART 3: PUBLIC PERCEPTION OF POWERLINE RIGHT-OF-WAY MANAGEMENT

CHAPTER 7

LITERATURE REVIEW

The Importance of Public Perception

Public perception of natural resource issues has been widely recognized as a critical managerial concern (Burnham et al. 1974, Mattfeld et al. 1984, Gutknecht 1991, Clark et al. 1995). Forest and wildlife managers must consider the acceptability of decisions and actions to their constituents in addition to environmental consequences. Land managers can preclude costly complaints, legal action, or restrictive legislation by consulting publics that have stakes in their activities (Tillman et al. 1984, Morris 1987). For public agencies or corporations, knowledge of public opinion may be necessary for formulating objectives or for evaluating completed programs (Grunig and Hunt 1984, Mattfeld et al. 1984, Medlin and Machlis 1991). Public awareness of an organization's concern for and investigation of public perception can even improve the image of that organization (McConnon 1981, Grunig and Hunt 1984).

Public Perception and Powerline ROW Management

Key public perception issues for powerline ROW managers include aesthetics, vegetation management efficacy, herbicide safety, and environmental effects of ROW treatments (Rosemarin and Wilson 1976, Ross 1979, Tillman et al. 1984, Priestley 1992, Clark et al. 1994). Elements of these issues have been studied in other contexts that are relevant to ROW management (Patey and Evans 1979, Buhyoff et al. 1984, Hull and Buhyoff 1986, Ribe 1989, Magill 1990, Magill 1992, Priestley 1992, Rhodeside and Harwell 1992).

For example, research on forest aesthetics has identified some general trends in public attitudes that may hold true for ROWs. Young, high-density forest types were rated low in beauty (Hull and Buhyoff 1986, Ribe 1989). Thick shrub cover (particularly in understories) was disliked by many (Patey and Evans 1979), as was slash, downed wood, and bare soil (Ribe 1989, Magill 1990, Magill 1992). Powerline corridors were almost universally regarded negatively. Corridors containing structures or vegetation that contrasted greatly with surrounding landscapes were usually more objectionable (Magill 1990, Entres Les Lignes 1991, Magill 1992, Priestley 1992, Rhodeside and Harwell 1992). Green cover was also preferred over snow, exposed soil, or other ROW coloration (Priestley 1992). Research results on corridor aesthetics will likely vary by geographic region and cover type, so area-specific study is necessary (Makowski 1990, Priestley 1992). However, because vegetation heights must be limited beneath powerlines, relatively few aesthetic alternatives need to be evaluated (Hull and Buhyoff 1986).

Although health and environmental safety is probably a more pressing public concern than purely aesthetic considerations (Burnham et al. 1974, Slovic 1990), relatively little research has been done on public perceptions of chemical applications (Ribe 1989, Howe 1990). Chemical concerns among participants in 1 study were highest for people who believed they lived in close proximity to a toxic dump site or to an area of high pesticide use (Howe 1990). People who own or rent property with ROWs are particularly sensitive to ROW management activities (Priestley 1990), and some may perceive the risks associated with herbicide use for ROW vegetation management to be intolerable.

In addition to cost and effectiveness, effects of land management alternatives on wildlife habitat and the environment are important concerns to many landowners and members of other publics (Kitchings et al. 1974, Kellert 1980, Tillman et al. 1984). No published research has directly addressed the many issues surrounding public perception of powerline ROW management (Clark et al. 1995). Identification of specific public concerns and values regarding ROW aesthetics, preferences among treatments, and perceptions of habitat management options would enable ROW managers to consider those concerns and values in designing and implementing ROW programs (Feher 1987).

CHAPTER 8

MATERIALS AND METHODS

Objectives

With direct input from the research sponsors, I developed the following objectives for this public perception research: (1) Identification of aspects of ROW management programs viewed positively or negatively by the public; (2) Determination of public preferences with regard to ROW vegetation and treatments; and (3) Elucidation of public attitudes about herbicide use in ROW and wildlife habitat management. Preconceived ideas about public attitudes can bias focus group results (Krueger 1988). I avoided formulating hypotheses to preclude such bias and because qualitative data are not suitable for testing hypotheses (Wells 1974, Bellenger et al. 1976, Greenbaum 1988, Krueger 1988).

Human Subjects Research Compliance

Because this research involved tape-recorded responses in the focus groups, thus creating more than minimal-risk involvement on the part of participants (Research Administration 1993), it was necessary to undergo human subjects research review by The University of Tennessee, Knoxville (UTK) Department of Forestry, Wildlife and Fisheries and the UTK Office of Research Compliances. I submitted a detailed

research protocol, including precautions to ensure participant confidentiality, which was reviewed and approved prior to contact with potential participants.

Focus Groups

Focus group interviewing (Greenbaum 1988, Krueger 1988), or group-depth interviewing (Goldman 1962, Wells 1974), was selected for an in-depth assessment of public attitudes about powerline ROWs management. Focus groups have been used extensively in marketing, consumer research, and other social sciences to obtain qualitative information about attitudes and beliefs about programs, goods, and services (Goldman 1962, Wells 1974, Krueger 1988, Kirk and Gillespie 1990, Trenkner and Achterberg 1991, Lewis and Yetley 1992, McCarthy et al. 1992). The technique is considered effective for base line attitudinal studies, for addressing target public concerns, for discovering motivations behind attitudes, and for laying groundwork for further investigations (Goldman 1962, Wells 1974, Greenbaum 1988, Krueger 1988). Focus groups have been used to survey attitudes about powerlines in general (Beauregard Conseil 1990, Entres Les Lignes 1991) and are being used increasingly in natural resource management applications (Medlin and Machlis 1991, Decision Sci. 1992, Duda 1992, Intelligent Market. Systems 1993, Clark et al. 1994).

Questioning Route

The first step in question development was identifying research questions (Figure 6) to be answered so as to meet the project objectives. These research questions, like the objectives, were reviewed by the project sponsors and the graduate

PUBLIC PERCEPTION OF POWERLINE RIGHT-OF-WAY MANAGEMENT

Research Questions

Right-of-way Treatments

1. What is the level of public knowledge about ROW treatments?
2. What aesthetic characteristics make ROWs more attractive?
3. Are there extant public preferences in the public among different treatments (e.g., brush cutting vs. herbicides)?
4. What practices make ROW management more acceptable?
5. How valued is landowner contact by the utility for ROW management?

Wildlife

1. What is the range of public perceptions of wildlife habitat?
2. Are ROWs perceived as wildlife habitat?
3. Is ROW management more favorably perceived if known to be inclusive of wildlife concerns?
4. Is herbicide use acceptable for producing quality wildlife habitat?

Herbicides

1. Does EPA approval of an herbicide matter to the public?
2. Are approved herbicides acceptable for ROW management?
3. What is the level of public awareness for the potential benefits and drawbacks of herbicide use?
4. Are there different attitudes toward different classes or types of pesticides?

Figure 6. Research questions for study on public perception of powerline right-of-way management in eastern Tennessee, 1993-1995.

committee co-chairs. I developed specific questions to be asked of focus group participants based on the research questions.

Focus group questions were designed to be open-ended to allow participants to share beliefs and attitudes, including those unanticipated. Questions were structured to be clear to a wide variety of publics. I used slides and explained definitions and other potentially technical information covered in the questioning route.

Participants

The sampling scheme for focus groups is dependent upon the publics of interest in a particular research effort (Krueger 1988). Generally, 2-3 groups per public provide sufficient data to identify the range of concerns and possibly even trends in attitudes within a public (Greenbaum 1988, Krueger 1988). When little new information surfaces in additional focus groups, nearly the full range of response types has been revealed (Krueger 1988).

Groups of 4-12 people each are desirable to facilitate group interaction while maintaining response depth. Each focus group was "homogeneous" in terms of the members having similar experiences with powerline ROWs (e.g., people with ROWs on their property) and having a similar residential status (e.g., living within the city limits of Knoxville) (Wells 1974, Krueger 1988, Schwaller and Shepherd 1992).

I identified 3 publics, whose members were active, interested or possibly affected (Grunig and Hunt 1984) by ROW management activities, from which to recruit participants in eastern Tennessee: (1) adults ($\geq$ 18 years of age) who are or have been owners or renters of property with electric transmission (high voltage)

powerline crossings; (2) the adult general public, or people who have never resided on property with transmission easements; and (3) civic groups interested in wildlife and natural resource management. Each participant took part in only 1 group.

The first public's recruitment pool, residents with powerlines, was compiled through county ownership/taxation maps in public administration offices (Krueger 1988). Phone numbers of easement holders that were not available on taxation maps were identified using telephone directories. Easement holders from this pool were randomized using phone numbers.

The second public's recruitment pool consisted of the adult general public in Knox and surrounding counties. Random numbers and a telephone directory were used to recruit participants from this pool (Dillman 1978, Krueger 1988).

The third recruitment pool consisted of civic groups or interest clubs. Contact persons for these interest groups were identified by faculty members of the UTK Department of Forestry, Wildlife and Fisheries and through the Knoxville Chamber of Commerce, which maintains a listing of active civic groups in the region.

Recruitment and Screening

I recruited participants for 2 preliminary (pilot-test) focus group interviews from civic groups. Due to lack of interest among other groups based on telephone contacts, announcements, and circulation of sign-up sheets at group meetings, I targeted recruitment at 3 groups with direct interest in environmental and land management issues. Members of a hunting club, an environmental group and a

wildlife interest group provided a sufficient number of potential participants for 2 focus groups.

At each group's meeting, I described the discussion topic and circulated a sign-up sheet for interested persons. I offered potential participants refreshments and a gift, which consisted of a package of UTK Agricultural Extension Service materials, as an incentive for participation. Follow-up recruitment consisted of telephone screening to eliminate past or present transmission line easement holders and electric utility employees (Figure A-1). I sent those who agreed to participate a personalized letter delineating the discussion details (Figure A-2) and reminded them of the discussion by telephone 1-2 days prior to the interview date. Because relatively few potential participants from the environmental and wildlife interest groups indicated an ability to attend an interview when screened by telephone, I recruited participants from these 2 groups for a single focus group.

I telephone-recruited potential focus group participants for the remaining groups 2-12 weeks prior to each scheduled interview (Greenbaum 1988, Krueger 1988). I recruited during evening hours using a script to ensure consistency (Figure A-1). The following 2 criteria were established as disqualifications for recruitment for a focus group: (1) the participant being a University of Tennessee employee, in which case the person could not be paid for their participation; and (2) the participant, a close friend, or a close relative working for an electric utility, which could bias the participant's attitudes and thus the interview results significantly.

Persons contacted who qualified based on screening were invited to a prescheduled focus group date. After the first 2 (pilot-test) groups were held, potential focus group participants were offered a monetary incentive to take part in a group interview (Krueger 1988, Trenkner and Achterberg 1991, Lewis and Yetley 1992). Potential participants for the first 4 post-pilot-test groups were offered $25, but due to low response rates, I increased the incentive to $50 for the final 3 groups.

I sent interested persons an information letter (Figure A-2), a payment authorization form, and a map to the focus group location as soon as they were recruited. I recruited as many potential participants as possible (generally 15) to offset attrition due to unforeseen conflicts with the discussion date. I reminded potential participants by telephone 1-2 days prior to each focus group date, at which time a final tally of participants was made and preferred first names were identified.

Informed Consent and Confidentiality

Informed consent (Research Administration 1993) was obtained from participants prior to interviews using a document which provided basic information to participants about risks and benefits associated with the research (Figure A-3). I also used a release form (Figure A-4) to acquire participants' permission to use their comments in publications and in this thesis. I stored the signed documents in a locked file cabinet to protect participant confidentiality; the documents will be held for 3 years from the date of their collection by the Department of Forestry, Wildlife and Fisheries to ensure compliance with federal regulations.

Only first names were used during focus groups, and these names were eliminated on transcripts using numeric coding. The lists of participants and phone numbers generated for recruiting were destroyed after groups were conducted.

Interviews

I moderated the focus groups (Hild 1984, Kolarcik 1987, Kirk and Gillespie 1990, Hyman 1991) after a thorough training period, which included studying focus-group interviewing instructional texts and published journal articles, observing live and video-recorded focus groups, and consulting with experienced moderators (Krueger 1988, Trenkner and Achterberg 1991, Gamon 1992). In 2 of the groups, another graduate student served as assistant, taking notes and summarizing group results. The moderator's assistant and I sought to maintain neutrality by not divulging our departmental affiliation unless directly asked, by indicating that my graduate research was in public opinion, and by attempting to answer questions in such a way as to not confer an opinion or judgement (Krueger 1988).

The first 8 focus group discussions were held in a conference room on the UTK Agriculture Campus (Krueger 1988, Wells 1974); the final interview took place in a Blount County Courthouse conference room. Each discussion lasted approximately 1.5 hours and was audio-taped for subsequent transcription. Fifteen minutes of refreshment and conversation preceded the actual interviews (Krueger 1988). I greeted participants outside the focus group room and initiated conversation about neutral topics such as the weather and participants' travel to the discussion location. At each interview's beginning time, participants and I entered the room

(Figure 7) and were seated. I placed name tents, indicating the preferred first names of participants, at particular locations around the table prior to the participants arriving, depending upon the verbosity of participants during the telephone screening (Krueger 1988). More outgoing and talkative participants were seated to the immediate sides of the moderator, whereas more reserved participants were seated across from the moderator to enhance eye contact and, thus, participation in the discussion.

I began interviews with a general introduction and coverage of basic ground rules (Figure A-5). I then followed the questioning route (Figure A-6) as closely as possible. I changed the order of questions as necessary depending on the discussion's progression. I set no fixed time frame for any particular question-answer series, but I directed diversions back to the prepared questions to ensure coverage of each major discussion topic.

At each group's conclusion, I administered a demographic questionnaire (Figure A-7) to obtain participants' background information (Schwaller and Shepherd 1992). I subsequently collected names and addresses for issuing payments by mail, thanked participants for taking part, and dismissed them. Payment checks were issued to participants by mail following interviews.

Transcription and Analysis

I transcribed each focus group discussion the day(s) immediately following each interview. I coded responses about each topic using HyperRESEARCH computer software (ResearchWare, Inc., Randolph, Mass.). Using HyperRESEARCH, I sorted comments by topic and response type, compiled lists of responses to each question and

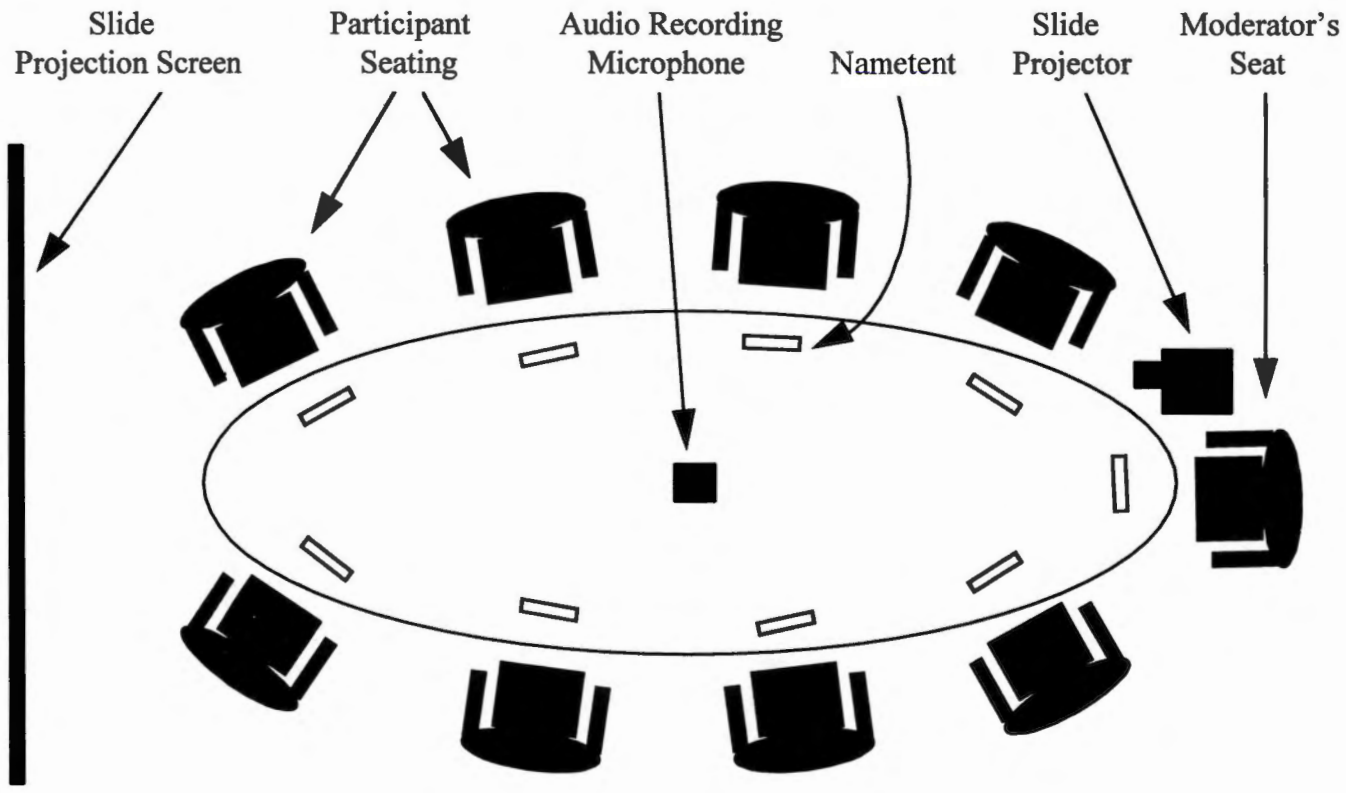


Figure 7. Typical interview room layout for focus groups held at the University of Tennessee, Knoxville, 1993-1995.

topic, and identified representative or poignant quotations. I analyzed results using HyperRESEARCH by tallying response types, categorizing responses, identifying the range of responses to questions, and identifying recurring or particularly interesting themes or ideas (Krueger 1988, Trenkner and Achterberg 1991, Lewis and Hollingsworth 1992). I also compiled participant demographics and analyzed responses for variation by residential setting, sex, race, age, education level and income.

CHAPTER 9

STUDY AREA

Most focus group participants were residents of Knox County, which occupies 1,317 km^2 of eastern Tennessee (Figure 8) land area and has a total population of approximately 336,000 (Bureau of Census 1992). Knox County is traversed by the Tennessee River, a navigable waterway, and is home to metropolitan Knoxville, in which roughly 50% of the county's residents live. Most residences in the county are urban (78%) and nonfarm rural (21.7%); farm residences total 0.3% (Bureau of Census 1992).

The county's major industries include agriculture, textiles, manufacturing, electronics, and communications (Tenn. Industrial Dev. Div. 1994). The county is in close commuting proximity to Cherokee National Forest and Great Smoky Mountains National Park to the south and east, and several surrounding state-administered forests, wildlife management areas, natural areas, and scenic rivers.

Knox County has a fairly balanced ratio of males to females (48:52) and is racially integrated primarily with whites (89%) and blacks (9%); Asians, American Indians, and other races total about 1% of the population (Bureau of Census 1992).

Household median income in 1989 was $26,010 (Bureau of Census 1992) and per capita income in 1992 was $17,382 (Tenn. Industrial Dev. Div. 1994). Educational attainment for Knox County residents $\geq$25 years of age is approximately

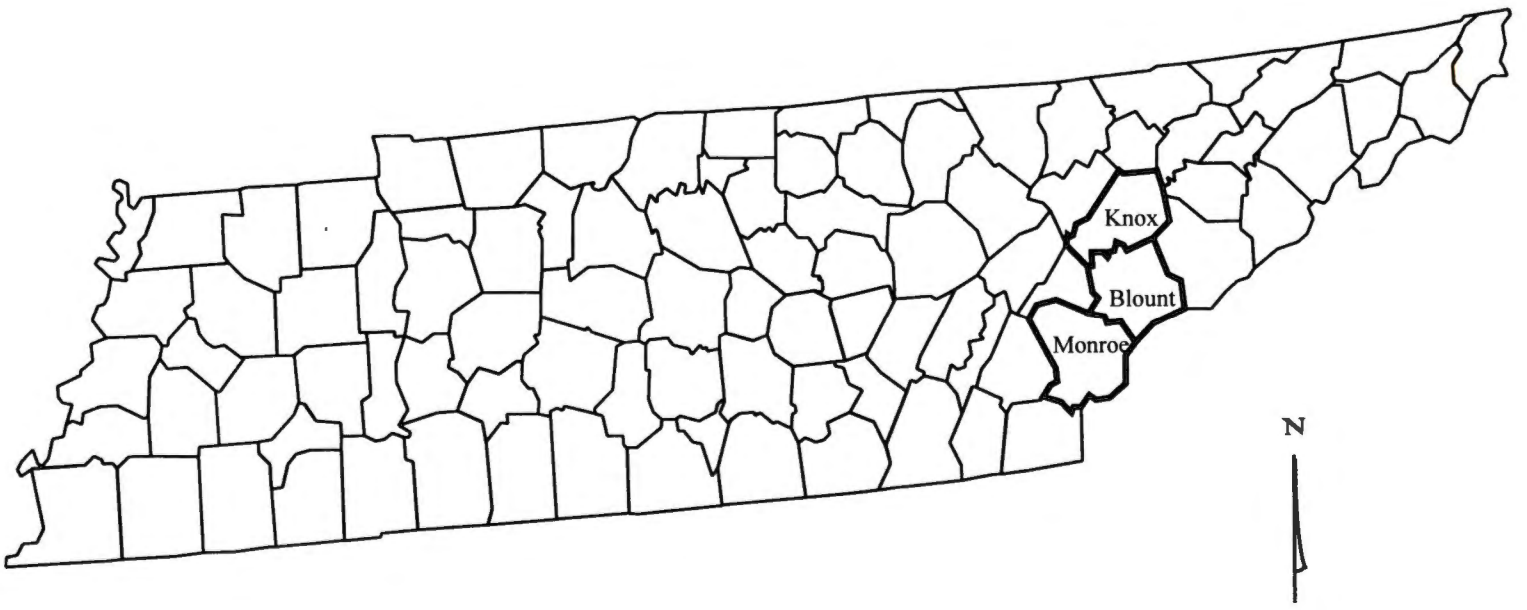


Figure 8. Location of counties represented by respondents in focus groups held in eastern Tennessee, 1993-1995.

parametrically distributed from elementary education to graduate degrees, with persons with less than ninth grade educations (11%), persons with 9-12 years of schooling (15%), high school graduates (27%), persons with some college (18%), and baccalaureates (15%) making up the majority (Bureau of Census 1992). Knox residents with graduate degrees constitute about 8% of the population.

Blount and Monroe counties were also represented by focus group participants in this study. Blount and Monroe counties have populations of approximately 86,000 and 30,500, respectively, and each has a slightly larger land base than Knox County (1,447 and 1,645 km^2, respectively) (Bureau of Census 1992). They also have proportionally fewer residents living in urban settings and proportionally more in rural settings compared to Knox County. Blount has a nearly balanced ratio of urban to rural residents (52:48), whereas most of Monroe's residents (73%) live in rural settings (Bureau of Census 1992). Percentages of residents living on farms in Blount and Monroe counties are 1.7 and 3.3%, respectively.

Median household incomes in Blount and Monroe counties in 1989 were $25,575 and $19,932, respectively (Bureau of Census 1992). These counties have populations with educational attainment distributions that are notably different from Knox County. The populations of Blount and Monroe counties have less formal education than that of Knox County. Fifteen % of Blount's residents $\geq$25 years of age have less than 9 years of school completed, 16% have 9 to 12 years of schooling, 33% are high school graduates, and 21% have some college or Associate's Degrees. Among Monroe's residents $\geq$25 years of age, 32% have attained less than ninth grade

educations, 18% have 9-12 years of school, 30% have high school diplomas, and 13% attended some college or earned an Associate's Degree. Those with Bachelor's degrees in Blount and Monroe number 6.4 and 10%, respectively, and those with graduate degrees total 3 and 5%, respectively (Bureau of Census 1992).

CHAPTER 10

RESULTS

Participants

Response Rate

I telephoned 1,054 households from potential focus group participant pools in eastern Tennessee to recruit participants. Only 13% met screening criteria and accepted invitations to participate; 37% of this group actually attended interviews. Fewer recruiting calls per group were required for the final 3 groups, presumably because the incentive amount was increased from $25 to $50. Percent of those attending based on telephone committal was also greater than prior groups, on average. A total of 51 participants were interviewed in 9 groups (Table 28).

Demographics

A majority of interview participants resided in Knoxville (n = 22), Farragut (n = 1), or Knox County (n = 18). Blount County was represented by 9 participants, 8 of whom took part in the final group interview; of these participants, 1 resided in Alcoa, 2 in Maryville, and 6 outside of city limits.

Twice as many males attended discussions as did females, although only slightly more males were recruited for groups. Racial distribution among participants was predominately Caucasian (90%), with 1 person from each of Asian, American Indian, American-Indian/Caucasian, black, and Hispanic descents participating.

Table 28. Publics included, numbers of participants, and dates of focus groups on powerline rights-of-way management, 1993-1995. All groups were held on the University of Tennessee, Knoxville campus except Group 9, which was held in a Blount County Courthouse conference room.

Public	Number of Participants	Date
Hunting Club	6	17 August 1993
Environmental Groups	3	16 May 1994
County Easement Holders	6	28 June 1994
County Easement Holders	5	19 July 1994
City Easement Holders	6	1 August 1994
City General Public	3	11 August 1994
County General Public	5	22 August 1994
County General Public	9	27 September 1994
County Easement Holders	8	17 January 1995

Participant ages were roughly normally distributed across categories (Figure A-7). One person from each of the oldest and youngest categories participated, but other age categories were represented by 5 to 13 people each.

All educational attainment levels (Figure A-7), ranging from elementary school to graduate degrees, were represented, though most participants indicating their educational background had 1-4 years of college (17.4%), 4-year degrees (17.4%), some graduate school (8.7%), or graduate degrees (30.4%). One to 4 participants represented each of the other educational levels, respectively. Focus group participants had notably higher educational attainments than the general publics of Knox, Blount and Monroe counties, as nearly 60% were college-educated ($\geq$ 4-year degree).

Annual incomes were fairly well distributed among categories offered on the demographic questionnaire. The income categories most frequently indicated were $20,000-$29,999 (19%), $30,000-$39,999 (19%), and $50,000-$59,999 (14.3%). As with educational attainment, income was skewed in the focus-group sample toward higher incomes. The general population from the 3 counties earned substantially less income, on average, than the 52+% of focus group participants who had incomes of $20,000 to $60,000. Nine participants did not report their incomes. Most participants (85%) did not farm for profit.

Participants and Focus Group Interviews

Participants spoke favorably about having participated in interviews. "I really enjoyed it" and "I found our discussion very interesting" were typical participant comments about their focus group experiences. Several also indicated their appreciation for research dealing with their interests and concerns about powerline ROW management. "I'm glad they care enough to ask us," 1 participant said.

Perceptions of Wildlife Habitat

Free Associations

When focus group participants were asked to associate the first word or phrase with "wildlife habitat" that came to their minds, responses ranged from a specific habitat component such as "cover" to a sentimental response such as "nature at its best." Most associations could be readily categorized by response type (Table 29). The most prevalent response types were objective, examples, and exclusive. "Food, water, and cover," and "home for wildlife," were frequent objective responses. Two participants specifically stated that habitat was "varied"--since wildlife may be "transitional and migratory, [habitat] can be many homes."

Exclusive responses, or those that indicated a perception of wildlife habitat as devoid of human intervention, were those given by participants who associated habitat with "protection" or "seclusion." "Natural," "undeveloped," "not planned or landscaped," "unimproved," and "away from cities; a place set aside" were typical exclusive responses. "Sanctuary," a word one person used, seemed to capture the

Table 29. Types of responses to free associations with "wildlife habitat" in focus groups on powerline rights-of-way management in eastern Tennessee, 1993-1995.

Response Type	Description of Response Types	Sample Responses for each Type
Objective	Definition or identification of specific habitat element(s)	"Cover, hiding places, and food;" "Where animals live"
Examples		
Simple	Example of one habitat type or habitat element	"forest with streams running through it;" "den or hole;" "food plots;" "jungle"
Complex	Examples of more than one habitat type or element	"woods, swamps, wetlands, fields;"
Exclusive	Ascribing quality of remoteness, protection, or exclusion of people from habitat	"nature, unpolluted by man;" "protected;" "undeveloped" "National Park;" "wilderness"
Valuative	Response with emotional or spiritual significance	"serenity, free spirits;" "exciting and adventurous"
Unfamiliar or No Response	Respondent had either never heard term before or had no association	"I've never heard of that before" "I didn't have any [response]"

substantive thrust of exclusive responses. One participant even mentioned enclosures or "fences" when discussing wildlife habitat.

"National park," another exclusive response, was also identified as the first thing that came to mind when some participants thought of "wildlife habitat." The protection afforded wildlife from harvest and housing development coupled with observer access in such places probably contributed to this perception some participants had of wildlife habitat. The proximity of our study area to Great Smoky Mountains National Park and participants' familiarity with the Park's observable wildlife was evident. One man associated "dens or holes" with habitat because he "automatically thought of the Smoky Mountains" and the bears there.

Two participants in different groups mentioned that their perceptions of habitat had been influenced by visits to Yellowstone National Park. One participant responded to another's habitat free association of "no people" by saying:

> "You *can* have wildlife in places where people are; that was really obvious to me recently when I went to Yellowstone National Park. The buffalo, the elk, the deer, the mule deer and everything else [were] roaming around out there and the place [was] full of people."

Another shared that she "used to think that you had to have all those trees" for habitat, but after observing Yellowstone's open areas and burned-over habitat that were productive for wildlife, she changed her mind.

Simple and complex examples of habitat types, such as the open spaces of Yellowstone, or habitat components were fairly common in habitat free associations. "Jungle," "forest," "trees," and "brush" were each mentioned more than once.

A few group participants expressed a lack of familiarity with the term "wildlife habitat" or declined to respond. "I don't know that I've heard it, but I just assumed it was wild animals' home," 1 such person said. Sentimental or valuative response types were observed least often. "Animals around...makes me happy" and "nature at its best" are examples of sentimental associations shared by a few participants.

Rights-of-way as Wildlife Habitat

Most participants responded to the question "Have you ever thought of a ROW as wildlife habitat?" in the negative, either because they had "really never thought about a powerline [corridor in] that way" or because they thought of ROWs as "cleaned out" and lacking habitat value. Several participants indicated that they perceived ROWs to be "exactly the opposite" of habitat since they were periodically cleared; they believed "animals don't like" areas like ROWs that seem "unprotected and barren."

Members of the hunting club, hunters, and participants who had personally seen wildlife in ROWs did believe utility corridors were usable for wildlife, or at least that they could be developed as habitat. One hunting club member said, "All powerline right-of-ways are usable for wildlife habitat." Another added, "rabbits, squirrels, fox, coyotes...they'll use openings like that along powerlines." The cultivation of food

plots was specified by hunting club members as a means to enhance wildlife use of corridors. An environmental group member similarly reflected upon her experience:

> "I've seen some wild turkeys and deer out in the cleared part, and as long as they've got the forest on each side or their own habitat, they might do some grazing out there in the low part."

A rabbit hunter felt that powerline corridors were "one of the best places in the world to rabbit hunt around because there is scrub-growth" for cover. A rural farmer commented, "it's good quail habitat, at certain stages, but then when they come through and whack all [the vegetation] down, then they've destroyed it all and it takes a year or 2 before the rabbits and the quail and everything else will start back [using the area]." A city resident acknowledged that the management of ROWs would "encourage some [wildlife species] and discourage others," but like several other participants in these groups, he seemed to be averse to the idea of wildlife management. "In terms of wildlife, it is no longer *wild* life--we've made an intervention--it has become managed," he said.

Preferences Among Right-of-way Cover Types

When asked to rank 3 vegetative cover types beneath transmission lines shown on slides (grass cover, low shrub-brush cover, and very tall brush cover) in terms of personal preference, participants overwhelmingly preferred the grass cover and shrub cover over the tall brush. Participants ranked the grass cover highest most often and usually described it as "neater" or more "productive" than other cover types (Table 30).

Table 30. Range of responses to photographic slides of transmission rights-of-way with different cover types in focus groups on powerline rights-of-way management in eastern Tennessee, 1993-1995.

Cover Type	Sample Descriptive Responses
Grass Cover	"It's alot cheaper to keep it cleaned out." "It's just more pleasing to the eye." "It's well kept." "It looks productive." "It would be a great place for birds and rabbits." "Natural." "Accessible." "Usable space." "You just see a big scar just climbing up and down hills. It has no appeal."
Shrub-Brush Cover	"It's in the middle and gives rabbits habitat and the young wildlife some place to hide." "It looks like it's been chopped...the land is useless for walking or anything else." "I liked the way it looked where it had waist-high or shoulder-high foliage" "I find it more attractive because the plants beneath that powerline appear to be greener, seemingly more dense."
Tall Brush-Cover	"Old growth and unkept;" "The right-of-way is filled in...it has a higher aesthetic to me than the grassland or the low shrub." "The least disturbed." "More natural; wild-looking." "Not usable." "Dangerous."

"Usable" was another common term used to explain the motivation behind participants' selections of the grass as most preferable. Participants said a ROW with grass cover could be used for purposes other than just power transmission, such as "soccer fields," walking trails, or "pastures." Several also mentioned that utilities' access to lines and structures would be facilitated by such low cover.

Many participants ranked the low shrub-brush cover first or second in terms of preference. Participants who liked this cover type often cited wildlife cover value and visual appeal as reasons for their selection.

Although the openness afforded by grass cover on ROWs was a quality favored by some, it was clearly disliked by others. Some identified the contrast between grassy ROW cover and surrounding forest as a "scar" on the landscape. They believed that tall brush would not create such a stark contrast, and that it would serve to screen electric facilities or "distract [a viewer's attention] from a powerline." One person stated that they thought tall cover would be "least expensive to maintain." Participants who expressed a dislike for tall brush cover on ROWs attributed their feelings principally to the lack of uses available on land with such cover and to its "unkept" appearance.

Knowledge of Right-of-way Management Methods

When prompted to share "methods used to maintain or manage ROWs that they were familiar with", the vast majority of participants with transmission ROWs crossing or adjacent to their property identified mechanical or manual cutting. Many such

participants were satisfied with the relationship they had with the responsible utility and with past vegetation management. Several participants, however, wanted a more regular treatment cycle so that cut brush would not create an eyesore on ROWs. "If they'd cut it regularly like they should, every 3 years or so, they could chop it up like grass, but this knocking it down and leaving it laying is bad." A few group participants angrily referred to brush-hogging large sapling stems as "mangling" trees and "raping" the land, and that such was "definitely not *management*." These landowners felt strongly that a relatively short (~3-year) brush-cutting cycle was the most economical, safe, and aesthetically pleasing means of ROW management.

Many participants from "general public" or special interest groups knew or offered guesses as to common methods of ROW management, including brush-hogging, hand-cutting with chainsaws, or herbicides. Among landowner and general public participants stating that they believed herbicides were being used to treat ROW vegetation in some areas, few had first-hand experience of seeing herbicides applied; most had either heard of herbicide use on ROWs ("I've heard of them spraying but I never have seen them spray") or had seen brown-out or other indications of their use (e.g., adjacent forest defoliated) and had drawn their own conclusions. One landowner remarked, "they do a lot of spraying around the powerlines; they spray those that are on our property at times, and I assume [they do it] with a helicopter." Another added, "I don't know what else could be killing off the trees that grew up near those lines or around them."

Perceptions of Herbicides

Free Associations

Participants gave a wide range of free associations with "herbicide." Response types ranged from objective definitions to positive or negative judgements (Table 31). A majority of group participants shared associations that were objective, denoting what herbicides are intended for (e.g., "chemical substance that is designed to destroy plant life," or "plant killer"), or examples, in which specific herbicides were mentioned--"Roundup" was mentioned most. Positive, negative, and cautious response types were fairly common; such responses included perceived attributes of herbicides or their use (e.g., "a lot of people would go hungry without them"), or identification of potential dangers of herbicides. One hunting club member gave a cautious association: "it may cause pollution or runoff problems, it may not, and like everyone else said, it might damage wildlife."

Some participants were unequivocally against herbicides and their use. One environmental group participant associated "everything is dead, brown, poisoned" with "herbicide." "Danger," "mutations of plants and critters; dead streams," and "pollution" were some negative associations with herbicides from other groups. Several thought of "DDT" (Dichloro-Diphenyl-Trichloroethane) and "Agent Orange" when hearing "herbicide;" many such participants later expressed skepticism regarding the value of herbicides based on the history of pesticide safety. "They used DDT for many, many years and they found out that it was bad news," 1 focus group participant said.

Table 31. Types of responses to free associations with "herbicide" in focus groups on powerline rights-of-way management in eastern Tennessee, 1993-1995.

Response Type	Description of Response Types	Sample Responses for each Type
Objective	Definition or identification of objective qualities of herbicide(s)	"a chemical used by man to control plant growth;" "weed killer"
Example	Identification of specific herbicide	"Roundup, Atrex, and so forth;" "Roundup"
Generic Pesticide or Chemical Association	Identification of herbicide with other pesticides or chemicals	"DDT and weed control;" "chemical"
Negative	Response was unfavorable toward herbicides	"Chemical pollutants injurious to everyone's health;" "wildlife destruction;" "No good"
Cautious	Response identified caution or concern	"Caution; check it out;" "Be careful."
Positive	Response was favorable toward herbicides	"Increased plant production;" "They've got some good ones."
Unfamiliar or No Response	Respondent had either never heard term before or had no association	"What is it?" "It sounds like some kind of chemical."

Few purely positive "herbicide" associations were offered. Most positive associations were from participants involved in production agriculture. Farmers also more readily articulated specific herbicide brands ("Atrex," "Spike") and modes of action ("selective" vs. "nonselective," "pre-emergent" vs. "post-emergent"). A few of those interviewed were ambivalent about herbicides, acknowledging their potential usefulness but alluding to perceived questionable or negative attributes ("not good but sometimes necessary)."

A few participants had no association or were unfamiliar with the term "herbicide." Some had heard the term, but were "not sure exactly what it means." One said, "I thought it was a defoliant of some sort; whether it's environmentally safe or not, I don't know."

Right-of-way Management with Herbicides

Responses to the question, "How would you feel about herbicides being used to treat the vegetation on ROWs?" were quite varied. However, the overriding concern expressed by landowners with powerline ROWs on their property was for landowner-utility contact prior to vegetation management with herbicides (or other means). Landowners felt this would enable them to voice concerns and ask questions about chemicals being proposed for use, and it would allow them to take actions (if necessary) to protect their interests, such as temporarily moving livestock out of a treated area.

Some landowners and members of other publics were adamantly against ROW management with herbicides. Some of their comments were:

•"I'm not in favor of it. To me, it's too dangerous;"

•"They can not convince me them herbicides don't run into where the fish and wildlife is. And let them go in there with their heavy equipment and do that rather than spray;"

•"I wouldn't be for using [herbicides] underneath the powerlines. I think the bush-hogging treatment is sufficient in cases where I've seen it, or the chainsaw in cases where [woody stems] get too big;"

•"I wouldn't want them to use [herbicides] anywhere for that purpose. Because of the appearance. Whether it was my property or someone else's wouldn't make any difference;"

•"I think it would be a dangerous hazard because you don't know what they're going to come up with in the future. Once they've got into the habit of using chemicals to keep the right-of-way clean then anything that came up in the future they would in theory have the right to [use]. I would feel more comfortable and a lot safer if they just weren't allowed to use them at all...period;"

•"Looking back, I think we've got too many examples of things that have happened with herbicides that tend to contradict anything that anybody would tell you that they could do with them;"

•"It seems like every time chemicals are introduced, they're bound to do some harm somewhere because you're upsetting a natural balance that was put there. I can't swear by that, it just seems to me...somewhere down the line, you're hurting something you didn't mean to hurt. Some animal would come up and eat the plant before it actually withers and dies, and die as a result of that;" and

•"I find myself being quite leery at times where the real cost savings and benefits [to utilities]...where is that [savings] going?"

A few landowners said they would even manage the vegetation themselves if confronted with herbicide use on ROWs as their only alternative.

Few landowners were unconditionally supportive of ROW management with herbicides. Many landowners said they would allow or consider herbicide use on ROWs depending on the proximity of treatment to homes and water sources, the characteristics of the herbicide being used, the application method, and the types of land use engaged on and around ROWs. Some landowners were specific about criteria or concerns they would like addressed concerning herbicide use on ROWs:

•"Keep it to a minimal amount; control it, and be very careful with it;"

•"[If] the chemicals aren't hazardous to your health;"

•"Very limited based upon the homeowner or property owner's opinion;"

- "If there was a small, long-term controlled area where they could prove [the chemical], and I don't know what long-term is--it may not be in 1 person's lifetime. It's hard to convince someone if they don't see the results in their own lifetime;"
- "I would like to be sure they've done sufficient studies to make myself feel like it's safe;"
- "The best [use of herbicides] is definitely spot-spraying, I believe;" and
- "As long as it don't pollute the ground or be harmful to humans or animals, I don't see a problem [with it]."

Some participants regarded herbicide application as more acceptable in "steep" or "rough" terrain conditions that preclude other vegetation management options. To them, the combination of remoteness from people and residences, and difficulty in accessing ROWs for brush-cutting in such conditions seemed to make herbicides a more reasonable alternative.

Habitat Management with Herbicides

Participants shared diverse sentiments when questioned about their feelings toward agencies using herbicides to improve wildlife habitat. Some felt that "if it could be shown to really benefit the wildlife, then [they'd] be for it." The concept of habitat management was familiar to relatively few, although 1 participant said, "I think there are a lot of parks--places that are nice to visit and see wildlife, etc.--that are not in their natural state; I can think of a lot of places where things have been [managed]." To many, though, the idea of manipulating plants or plant associations,

particularly with herbicides, to benefit wildlife was foreign. For example, participants in interviews said:

- "I would believe if they told me [they were using herbicides for that purpose] that it would be like so many other things government agencies have told you--they just didn't know what they were talking about;"
- "Someone would have to explain that to me because I don't relate herbicides with promoting or improving anything;"
- "I'd think it would be a waste of money--better to just let it live naturally;" and
- "The plants around here are native to this region. So are all of our fish, game, whatever. They're adapted to the environment as well as anything else. So why would we need to systematically kill off certain plants for that reason [habitat improvement]?"

A few participants were "unsure about it" or didn't "have enough knowledge to have an opinion."

Benefits and Drawbacks of Herbicide Use

When focus group participants were asked to identify potential benefits and potential drawbacks of herbicides for ROW management, most more readily identified potential drawbacks. Perceived health and environmental risks were mentioned most as drawbacks (Table 32). Potential benefits ranged from cost savings to better woody vegetation control to improved ROW aesthetics (Table 33); economics, ease of application, and effectiveness were benefits most frequently mentioned.

Table 32. Potential drawbacks associated with herbicidal treatment by respondents in focus groups on powerline rights-of-way management in eastern Tennessee, 1993-1995.

Potential Drawback	Sample Descriptive Responses
Environmental and Health Effects	"It may cause pollution;" "It can run into streams and get into the food chain."
	"Personal health risks or effects;" "Human and animal health."
	"When they use that total killing herbicide you wind up with no habitat whatsoever;" "[You may be] upsetting the whole balance of things."
	"The wrong stuff comes back a lot of times." "Plants [may] become immune to it."
	"I think it also creates a fire hazard unless [the ROW is] cleaned out right."
Long-term Unknowns	"Economically, [herbicides may be] the best thing to do at that point in time [but] 30, 40, 50 years later it may not be. I think we need more data on herbicides and the application of herbicides." "Sometimes chemical effects are irreversible."

Table 32. (continued)

Potential Drawback	Sample Descriptive Responses
Public Perception	"You're not going to be able to use it around people;" "Environmentalists won't let you."
Labor Reduction	"Employment;" "I would think that there would be fewer jobs as opposed to the number that would be needed to clear [ROWs] manually."
Aesthetics	"If it kills the plant life or withers it up and makes it brown it's not going to very appealing, and it's definitely not going to fit into the countryside."
Application Errors	"If the wind blows or if it drifts it will arch off and take out a good piece of the surrounding woods;" "Accidental leakage; improper use."

Table 33. Potential benefits associated with herbicidal treatment by respondents in focus groups on powerline rights-of-way management in eastern Tennessee, 1993-1995.

Potential Benefit	Sample Descriptive Responses
Cost savings	"Economics. I'm sure it's the most cost-effective way to solve the problem." "The tractors and mowers needing maintenance or occasionally breakdowns, as compared to just the maintaining the sprayers with the herbicide." "It will save labor."
Employment	"Jobs with the chemical company."
Ease of Treatment	"I'm sure the convenience and speed would be beneficial with herbicides." "The steepness of a mountainside, you can't mow."
Effectiveness	"It would slow down the [plants] growing" and "probably...for a longer period of time."
Aesthetics	"In theory, the ideal herbicide would yield grass cover, and I find it much more attractive."

Government Regulation of Chemicals

In general, participants' knowledge of pesticide registration was extremely limited. Only group participants with government agency or chemical-related work experience responded to the question, "Are you aware of how an herbicide gets government approval for use?" with even a basic understanding of the extent of testing, financial expenditure, and time invested in securing governmental approval for herbicide distribution. There was a general impression that "it takes a lot of testing" and that the government "tightens their regulations as years go by," but few could even identify the Environmental Protection Agency (EPA) as the responsible regulatory agency.

Few participants appeared to be swayed by a general description of the EPA's herbicide registration process (Figure A-6). Although many were more comfortable knowing that some definitive safeguards were in place, nearly all participants were skeptical of the regulatory process. First, bribery and politics were directly referenced or alluded to in nearly every group. A number of participants felt that chemical approval was contingent upon "whether the money's good." Second, the source of chemical testing data was suspect to many participants. "I think it's really hard to find anyone who doesn't have a vested interest and who is really objective about something like this," 1 participant shared. Another added, "Two things I really hate are: 'studies have shown' and 'what if;' all you have to do is mention those and you either prove or disprove anything you want to without falsehood." Third, some participants were concerned that older chemicals may be "grandfathered," or allowed to remain on

the market based on outmoded registration research. Those participants wondered about the specifics of herbicide re-registration.

Some participants felt that "because of lawsuits," or the threat thereof, the EPA was sufficiently cautious ("with all these ambulance-chasing lawyers running around, they're going to be careful...I have confidence in them") or perhaps overly cautious in its regulation. Some participants felt such "strain[ing] at a gnat and swallow[ing] a camel" leads to either: (1) pesticide users ignoring real safety concerns ("If you read the entire [pesticide] label you would never [use them]...if you believe [it all], *really*, you would *never*)" or (2) elimination of truly beneficial products ("They might find a cure for cancer, but they won't pass FDA [Food and Drug Admin.]").

Reactions to Tebuthiuron

The slide and description of tebuthiuron (Figure A-6) generated great interest among some participants, whereas many appeared to regard the chemical with the same skepticism shown in the preceding, general discussion of herbicides. The hunting club responded most favorably as a group--"that sounds like what we've been looking for" and "it sounds too good to be true"--although members had concerns about the cost, treatment cycles required, and application of the herbicide in areas with cultivated wildlife food and cover plants. In this light, 1 member said the acceptability of tebuthiuron treatment "would depend on the location and what was there for the wildlife."

Some participants were concerned with the "caution" rating of tebuthiuron, despite my explanation that the rating was on the lower end of the EPA's toxicity

schedule. That tebuthiuron is applied in pellet form sounded beneficial to hunting club members, because the chemical would not flow directly into the soil, and possibly into the water table, like a liquid, but other group members were concerned that wildlife ("rabbits and deer" or "birds") or children might selectively ingest the pellets.

Most of the other concerns expressed about tebuthiuron were similar to those voiced during dialogue about herbicides in general. "It probably does the same job as a lot of others; that's what I thought about it," 1 person responded. The fact that tebuthiuron had been EPA-registered since 1979 was a consolation to some, but others would have felt "a lot safer" if it was "approved in 1989" or more recently because of technology and policy changes. Many participants wanted specific explanations of the application method, rate, phytotoxicity mechanism(s) and mode of action, means of environmental decomposition, life and movement in soils and plants, and toxicological, mutagenic, and teratogenic properties of tebuthiuron before judging it.

Three landowners with ROWs on their property were familiar with tebuthiuron or a similar herbicide. Two had heard of tebuthiuron (1 used the trade name "Spike") but had not seen results in the field, and 1 said tebuthiuron or a similar chemical had been applied to a distribution line adjoining his property. He indicated that the treatment was fairly recent and was targeted at eliminating vines, but as yet he had seen no notable effects. Members of that group and several others were interested in first hand and area-specific research on tebuthiuron. "I would tend to believe somebody like him--who has an actual, practical application of it on his property--[more] than I would some test result," a fellow group member said. A

participant in a different interview "wonder(ed) if there's been enough studies in different parts of the country" to conclusively assess tebuthiuron's effectiveness. The desire for trustworthy information from another landowner or from an objective research organization was clearly evident across groups. "Who did the research would matter; I would trust UT research moreso than the chemical companies," articulated 1 participant who expressed such a desire.

CHAPTER 11

DISCUSSION

Focus groups were effective in answering this study's research questions (Figure 6):

1. Members of all publics were aware that brush cutting was a principal ROW management tool, and several believed or knew that herbicides were being used on some ROWs. Participants who had never thought about the management of ROWs easily guessed "mowing" or "cutting," or in some cases, "spraying." The effects of both methods of ROW management tend to be obvious, so these results seem reasonable, even for people who are not normally exposed to ROW management activities.

2. Participants identified a variety of aesthetic qualities that made ROWs more appealing. Most liked the "neat[ness]" of "pastoral" grass or shrub cover as opposed to tall brush growth on ROWs. My findings were similar to those of other researchers (Patey and Evans 1979, Hull and Buhyoff 1986, Ribe 1989, Priestley 1992), in that dense, young trees and shrubs were perceived as unkempt, and green, park-like settings were generally preferred. Participants attributed wildlife benefits, easy line and ROW maintenance, and easy access to low ROW growth. A few liked tall vegetation on ROWs because of the lack of contrast with surrounding forest lands, because it provided wildlife habitat, or because it seemed less expensive to maintain.

3. Most participants preferred brush-cutting over herbicide use on ROWs. Few approved of managing ROWs with herbicides without specific stipulations such those ensuring environmental and human safety. The possibility of large-scale herbicide application probably appealed to participants' fear of unknown health and environmental risks (Howe 1990); some participants were quite candid about those fears. Some viewed "spot spraying" and "selective" herbicide application as the only "proper use" of chemicals for controlling plant growth, perhaps because they perceived better application control translates into less risk (Howe 1990, Slovic 1990); these participants identified broadcast, nonselective applications as unacceptable.

4. Several landowners indicated that more frequent cutting, disposal of slash, and consideration of their yard and land management objectives were important. Many participants partially based their decisions on whether ROW practices were beneficial or detrimental on the perceived wildlife habitat effects.

5. Landowners and members of other publics resoundingly supported direct landowner contact prior to any ROW management activity. Although several landowners expressed satisfaction with past ROW vegetation management work, no focus group participant said he or she would rather not be contacted prior to such work being done. Participants felt that their interests were important because they owned or rented their property, paid their utility bills and taxes on their property, and had a personal stake in the effects of management operations.

6. Public perceptions of wildlife habitat were diverse, and ranged from a preserve or "sanctuary" to "food plots." Habitat was often associated with "natural"

areas, "park[s]", or "forest[s]." Relatively few associated management with habitat. Kellert (1980) found widespread concern about wildlife habitat. These results indicate a lack of widespread public appreciation of the potential for proactive land management to benefit wildlife.

7. Focus group participants tended to view ROWs as devoid of value to wildlife, unless they had observed or hunted wildlife in ROWs before. Direct, personal experience with wildlife appeared to be a critical factor affecting participants' views of habitat and its management, both on ROWs and elsewhere. An elderly female birdwatcher, for example, felt strongly that management favoring shrubby vegetation on ROWs could benefit songbirds and eastern cottontails--she had seen them using a regenerating, cut-over ROW adjacent to her property.

8. Except for hunters, participants were largely skeptical that human manipulation of vegetation could benefit wildlife (except for "kudzu" or other "pests"). These results suggest that it may be difficult to persuade people without direct wildlife experience that management can improve wildlife habitat without educational efforts.

9. Only a small percentage of participants felt that herbicide usage for habitat improvement was worthwhile. Most concluded that risks outweighed benefits and that "there's gotta be a better way" to manage wildlife habitat, if any management was to be done. Additional research that identifies potential tradeoffs between wildlife habitat improvement and economic or other costs could help managers better address constituent concerns or formulate education programs (Grunig and Hunt 1984).

10. Most participants had little knowledge of EPA's regulation of herbicides. Even after hearing a description of the time, money, and testing involved in pesticide registration, participants were still cynical toward the regulatory process. One apparent driving force behind participants' ubiquitous skepticism of herbicides was the history of pesticide registration and, later, withdrawal due to unforeseen toxicological effects. This was evidenced by numerous references to DDT and Agent Orange. Another important force in shaping public perception appeared to be sources of information on pesticides and the credibility of those sources. Participants showed cynicism toward almost every institution named as an herbicide information source, including news media, federal and state governments, chemical companies, and private laboratories. Information from universities appeared to be more favorably perceived, although some participants identified the pressures to "publish or perish" as possible sources of bias in university research. Several participants wanted data from eastern Tennessee studies on tebuthiuron's effects. Thus, the results from this study should be helpful for ROW and habitat managers considering tebuthiuron or other herbicide applications in the future.

11. Registered herbicides were generally perceived with caution, though some trusted the research and documentation behind EPA-approved chemicals.

12. Overall, participants much more readily identified potential drawbacks of herbicide use than potential benefits. Most drawbacks were related to human health, water pollution, and long-term, unknown risks. Economy and effectiveness were most specified as benefits. As other authors (Witt 1988, Slovic 1990) have noted, many

were reluctant to acknowledge benefits associated with certain technologies if any risks were perceived. This was apparent for some participants in this study.

13. Although some participants had different views about insecticides and herbicides, respectively, a majority thought of different classes of pesticides in similar terms; "DDT" was associated with herbicide often. Some participants related the food and drug regulatory system to that of pesticides. Most participants appeared to be unaware of the differences between the chemical pathways of different pesticides, such as insecticides versus herbicides.

I observed no clear trends in response types by demographic characteristics. However, my sample was skewed--participants were predominately well-educated compared to the remainder of eastern Tennessee's population, and the vast majority were white males. The education levels and affluence of many participants may explain why there was ubiquitous apprehension about herbicide use. It could be that those who have more formal education are more sensitive to environmental risks and more skeptical of pesticide policy development and implementation. The well-educated group represented in this study possessed minimal knowledge about government pesticide regulation; the general population probably possesses even less. Farmers appeared to be more familiar with specific herbicide trade names, effects, and benefits, and they appeared less prone to be adamantly against herbicides. Personal experience probably plays an important role in affecting beliefs and attitudes about pesticide use.

The nature of concerns focus groups participants expressed about herbicides were similar to those reported by Vaughan (1990), who listed factors that influence how risk associated with a substance is perceived. Those factors included: (1) a substance's persistence in the environment and in body tissues, (2) the familiarity of a substance, (3) whether a substance is carcinogenic, (4) whether research was conducted with humans or animals, because data on effects on humans appears to be much more trusted by the public, and (5) the personal relevance of consequences. Nearly every concern about pesticides that arose in focus groups was directly related to 1 of these factors.

Many focus group participants showed a strong desire to be heard by organizations involved in ROW and wildlife management. Many participants expressed appreciation for "being asked" to share their perceptions and attitudes, and a few requested access to this study's results. Landowners were emphatic about their being contacted by ROW managers prior to treatments being administered. They felt such contact would allow them to better protect their health, environment, and property.

Landowners who were opposed to herbicide use on ROWs were especially adamant about contact with utilities prior to ROW treatment. Some landowners indicated they would opt to manage the ROW themselves if given prior notification about imminent herbicide use on their property. Participants in several groups felt that herbicidal management of ROWs may be justified in "remote" and "inaccessible" places, such as in mountainous areas. Acceptance of herbicide use in rural localities

probably was related to economic benefits ("more cost effective") and minimal personal contact with herbicides ("away from people").

Vaughan (1990) stated the need for area-specific public perception research both for understanding the specific factors that drive attitudes toward substances such as pesticides and for allowing better predictions about people's response to potentially useful chemicals. This research provides evidence that personal experience with chemicals, information sources, and land management practices are important factors in shaping beliefs and attitudes about herbicides and their potential for land management in eastern Tennessee.

PART 4: MANAGEMENT AND RESEARCH IMPLICATIONS

CHAPTER 12

INTEGRATING HUMAN AND WILDLIFE CONCERNS

Tebuthiuron treatment appeared to reduce tree density, height, and overall dominance, and cause increased dominance by grasses and sedges, and forbs on 2 powerline ROWs on the University of Tennessee Oak Ridge Forest. These changes affected various wildlife species differently (Hamel 1992, Robinson and Bolen 1989). In general, this treatment benefitted species that require low-growing herbaceous habitat for food or cover. Typical species identified included red-tailed hawks, grasshopper sparrows, wild turkeys, and northern bobwhites. Species favoring tree- or brush-dominated habitats, such as prairie warbler, gray fox, ruffed grouse, and wood thrush, would probably not benefit from tebuthiuron treatment. The objectives of the land manager, the seasonal habitat requirements of target wildlife species to be managed for, and the landscape-level setting of the ROW (or other management area) are all important in determining the ultimate benefits of tebuthiuron treatment.

Most landowners with ROWs on their property, members of interest groups, and members of the general public who were interviewed preferred brush-cutting to broadcast herbicide use for ROW management. Many participants were willing to endorse herbicide use in remote areas, on rugged terrain, or in limited or selective applications. Some felt that as long as the herbicides used were safe and cost-effective they should be incorporated into ROW management programs.

Tebuthiuron was unfamiliar to the vast majority of focus group participants. Participants largely showed the same skepticism of tebuthiuron's safety and efficacy as they did toward other pesticides. A majority of participants wanted detailed information on toxicity, research sources, mode of action and fate, and cost before formulating opinions about tebuthiuron. It would be important for ROW and habitat managers to communicate such information to landowners or constituents to address the concerns of these groups.

The results of this research suggested that common interests among ROW managers and wildlife managers can be capitalized on for the benefit of wildlife and people. One such interest is in management of ROWs for grass or shrub cover. This management scheme would not only be liked by most landowners and members of the public for aesthetic or other reasons, but it would also contribute to a stable and useful habitat for wildlife species such as grasshopper sparrows, small mammals, and upland game such as northern bobwhites and white-tailed deer.

Another link between human and wildlife concerns shown in these results is the importance of public perceptions and attitudes. Most focus group participants were appreciative of the opportunity to share their views, and many had strong feelings about wildlife management issues, particularly herbicide use. In the Knoxville region, there may be serious barriers to using herbicides for ROW and habitat management. In addition, focus group results indicate that many people want ROWs and other lands managed for multiple benefits, including wildlife, recreation, and aesthetics. Agencies or organizations involved in ROW and habitat management must effectively work with

landowners and interest groups to communicate management objectives, acknowledge and integrate landowner or public goals if possible, and allay concerns about vegetation manipulation practices as they arise.

A final clear link between human and wildlife considerations demonstrated in this study that managers should emphasize is information and education. Relatively few focus group participants recognized ROWs or other managed areas as wildlife habitat, and even fewer expressed belief that land management could benefit wildlife. Many participants recognized the importance of parks and other protected areas to wildlife conservation. These areas only account for a small percentage of total land area in the U.S. Landowners and other publics need to recognize the important role private property plays in wildlife management. Education in this area is clearly needed. Developing and carrying out education programs can be difficult. Education programs, however, are critical for providing objective information that might not otherwise be received by the public (Giles 1978).

CHAPTER 13

RESEARCH NEEDS

Little research has been conducted on public perceptions of herbicides and ROW issues in general (Slovic 1990, Vaughan 1990, Clark et al. 1995). Attitudinal data are critical for agencies involved in managing public lands (Mattfeld et al. 1984). The results of this study could be used to develop a quantitative inventory of public perception of powerline ROW management in this or other regions (Krueger 1988). Key topics that should be addressed in such an inventory are perceptions of wildlife habitat, trusted sources of information on pesticides, and preferences among ROW treatments and ROW cover types. Quantitative research on ROW aesthetics may also identify landscape elements preferred by entire populations that can be managed for on an entire transmission system (Patey and Evans 1979, Buhyoff et al. 1984, Priestley 1992). Focus group or survey research across a more diverse participant base may yield different results than presented here; follow-up research is recommended, especially if extrapolation of results is desired (Greenbaum 1988, Krueger 1988).

Tebuthiuron appears to be a useful tool for managing ROWs and other habitats where herbaceous cover is preferred over brush, although high application rates may eliminate even herbaceous vegetation under certain circumstances (Doerr and Guthery 1983, Defazio 1986, Fulbright and Garza 1991). Although sampling in this study was extensive, additional research is needed to more fully determine effects of tebuthiuron

on different vegetation types and habitats in the Southeast (Defazio et al. 1988*a*, Thompson et al. 1991). Also, focus group participants were interested in research on tebuthiuron's motility in soils specific to the soil types and landforms of eastern Tennessee. Such research would enable natural resource managers to gauge tebuthiuron's stability in soils in this region and more confidently respond to constituent concerns about runoff effects from the herbicide's use.

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APPENDIX

Table A-1. Trees occurring on strip transects on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Species and Author	Common Name
Acer saccharum Marsh.	Sugar Maple
Acer rubrum L.	Red Maple
Amelanchier arborea (Michx. f.) Fern.	Downy Serviceberry
Aralia spinosa L.	Devil's Walking Stick
Asimina triloba (L.) Dunal	Paw Paw
Carpinus caroliniana Walt.	Ironwood / Blue Beech
Carya ovata (Mill.) K. Koch	Shagbark Hickory
Cercis canadensis L.	Redbud
Cornus florida L	Flowering Dogwood
Crataegus spp. L.	Hawthorn
Ilex opaca Ait.	American Holly
Juglans nigra L.	Black Walnut
Juniperus virginiana L.	Eastern Red Cedar
Liquidambar styraciflua L.	Sweetgum
Morus rubra L.	Red Mulberry

Table A-1. (continued)

Species and Author	Common Name
Nyssa sylvatica Marsh.	Blackgum
Oxydendrum arboreum (L.) DC.	Sourwood
Pinus echinata Mill.	Shortleaf Pine
Pinus strobus L.	White Pine
Pinus virginiana Mill.	Virginia Pine
Platanus occidentalis L.	American Sycamore
Prunus serotina Ehrhart	Wild Black Cherry
Quercus alba L.	White Oak
Quercus falcata Michx.	Southern Red Oak
Quercus montana Willd.	Chestnut Oak
Quercus rubra L.	Northern Red Oak
Quercus velutina Lam.	Black Oak
Rhamnus caroliniana Walt.	Carolina Buckthorn
Rhus copallina L.	Winged Sumac
Rhus glabra L.	Smooth Sumac
Robinia pseudoacacia L.	Black Locust
Sassafras albidum (Nutt.) Nees	Sassafras
Ulmus spp. L.	Elm

Table A-2. Shrubs occurring on strip transects on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Species and Author	Common Name
Lespedeza bicolor Turcz.	Bicolor Lespedeza
Rosa multiflora Thunb.	Multiflora Rose
Rhododendron spp. L.	Azalea
Rubus spp. L.	Brambles / Blackberries
Vaccinium angustifolium Torr.	Lowbush Blueberry

Table A-3. Vines occurring in quadrats quadrats on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Species and Author	Common Name
Lonicera japonica Thunb.	Japanese Honeysuckle
Parthenocissus quinquefolia (L.) Planch.	Virginia Creeper
Smilax spp. L.	Greenbrier / Catbrier
Toxicodendron radicans (L.) Kuntze	Poison Ivy
Vitis spp. L.	Grape

Table A-4. Grasses and sedges occurring in quadrats on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Species and Author	Common Name
Andropogon ternarius Michx.	Bluestem / Broomsedge
Andropogon virginicus L.	Broomsedge / Broomstraw
Carex nigromarginata Schweinitz	Black-Margined Sedge
Carex spp. L.	Sedge
Cynodon dactylon (L.) Pers.	Bermuda Grass
Erianthus alopecuroides (L.) Ell.	Silver Plume Grass / Beard Grass
Muhlenbergia frondosa (Poir.) Fern.	
Panicum acuminatum Swartz	
Panicum anceps Michx.	
Panicum capillare L.	Witch Grass
Panicum clandestinum L.	
Panicum commutatum Schultes	Deer-Tongue Grass
Sorghastrum elliottii (Mohr) Nash	Indian Grass
Tridens flavus (L.) Hitchc.	Purpletop

Table A-5. Forb and fern species occurring in quadrats on 2 powerline rights-of-way in eastern Tennessee, 1992-1994.

Species and Author	Common Name(s)
Allium spp. L	Wild Onion
Ambrosia spp. L.	Ragweed
Amphicarpaea bracteata (L.) Fern.	Hog Peanut
Asclepias spp. L.	Milkweed
Asplenium pinnatifidum Muhl.	Lobed Spleenwort
Asplenium platyneuron (L.) BSP.	Ebony Spleenwort
Aster dumosus L.	
Aster patens Ait.	Late Purple Aster
Aster spp. L.	Aster(s)
Barbarea spp. R. Br.	Wintercress
Cassia fasciculata Michx.	Partridge-Pea
Cassia nictitans L.	Sensitive Plant
Cirsium spp. Mill	Thistle
Crotalaria sagittalis L.	Rattlebox
Desmodium spp. Desv.	Tick Trefoil / Beggar Lice

Table A-5. (continued)

Species and Author	Common Name(s)
Eupatorium aromaticum L.	Snakeroot
Eupatorium fistulosum Barratt	Joe-Pye Weed
Galactia volubilis (L.) Britt.	Milk Pea
Galax spp. Raf.	Galax
Galium spp. L.	Bedstraw
Geranium spp. L.	Wild Geranium
Gnaphlium obtusifolium L.	Sweet Everlasting
Helianthus microcephalus T. & G.	Sunflower
Hexastylis arifolia (Michx.) Small	Little Brown Jug
Ipomea spp. L.	Morning Glory
Krigia biflora (Walt.) Blake	Dwarf Dandelion / Cynthia
Lespedeza cuneata (Dumont) G. Don	Sericea Lespedeza
Lespedeza hirta (L.) Hornemann	Hairy Bush-Clover
Lobelia puberula Michx.	Downy Lobelia
Microstegium vimineum (Trin.) Camus	Willow Grass
Oxalis stricta L.	Yellow Wood-Sorrel
Plantago spp. L.	Plantain

Table A-5. (continued).

Species and Author	Common Name(s)
Polymnia canadensis L.	Small-Flowered Leafcup
Polystichum acrostichoides (Michx.) Schott	Christmas Fern
Pteridium aquilinum (L.) Kuhn	Brachen Fern
Rudbeckia triloba L.	Brown-Eyed Susan
Ruellia caroliniensis (J. F. Gmel) Steudel	Wild Petunia
Sanguinaria canadensis L.	Bloodroot
Scutellaria integrifolia L.	Skullcap
Senecio anonymus A. Wood	Ragwort / Groundsel
Solanum carolinense L.	Horsenettle
Solidago spp. L.	Goldenrod
Taraxacum officinale Weber	Dandelion
Uvularia perfoliata L.	Perfoliate Bellwort
Verbascum thapsus L.	Common Mullein
Verbesina occidentalis (L.) Walt.	Yellow Crownbeard
Verbesina virginica L.	White Crownbeard
Viola sororia Willd.	Blue Violet
Waldsteina fragaroides (Michx.) Tratt	Barren Strawberry

Focus Group Screener

-----Hello (Adult).

Good evening. I'm conducting a survey of people in the community for the University of Tennessee, and I would like to ask you a few general questions. It will only take about a minute. Is it OK to begin?

-----Yes

Is there a large, high-voltage powerline, a transmission line, crossing your property?

-----Yes or No

Do you, a close friend, or a close relative work for a utility?

-----No

Are you between the ages of 18 and 65?

-----Yes

Are you an employee of the University of Tennessee?

-----No

Do you live within the city limits of Knoxville?

-----Yes or No

Do you own or rent land or property in the county?

-----Yes or No

Based on your responses, we would like to invite you to a special meeting we're holding at the University of Tennessee to discuss powerlines. There will be no selling involved in the meeting, and if you decide to attend we will pay you $__ for your participation and we would provide refreshments for the discussion. The meeting will be an informal small group discussion, and your participation would be confidential.
The meeting will be held on _____ from 6:45 to 8:30 p.m. It will be on the UT, Knoxville campus. Would you be interested in joining us?

Yes-----Great. I'll send you a letter of confirmation in the mail. Could I please have your address? O.k., I will get a letter out to you in a few days, and I will give you a telephone reminder a few days before the meeting. Thank you very much for your time. We value your participation in this research. Good-bye.----------

No------OK. Thank you for your time and cooperation. Good-bye.---

Figure A-1. Sample screener used to recruit participants for focus groups on public perception of powerline right-of-way management in eastern Tennessee, 1992-1994.

THE UNIVERSITY OF TENNESSEE

Brian N. Clark
274 Ellington Hall
P. O. Box 1071
Knoxville, TN 37901-1071
(615) 974-3927

8 September 1994

(Respondent Name)
(Respondent Address)

Dear (Respondent Name):

Thank you for accepting our invitation to attend the discussion on powerlines. It will be on Thursday, September 22 in Ellington Plant Sciences Building Room 128 at the University of Tennessee, Knoxville, on the Agricultural Campus. A map is enclosed for your convenience. Please join us for refreshments at 6:45 p.m.; we will begin the discussion shortly after that time. It will last until approximately 8:30 p.m.

Since we are talking with a limited number of people, the success and quality of our discussion is based on the cooperation of the people who attend. Because you have accepted our invitation, your attendance at the session is anticipated and will aid in making the research project a success. The discussion you will be attending will be a forum of people who live around Knoxville and have not lived on property with a high voltage powerline crossing their property. Please dress casually and comfortably.

This is strictly a research project, and no sales or solicitations will be made. At the conclusion of the discussion I will be requesting you and other participants to provide some information on a University of Tennessee payment authorization form, which our accounting office will use to send you your $__ payment by mail. A copy of the form is enclosed, and you may complete it prior to coming for the discussion if you like.

Please do not prepare for the discussion by talking to others about powerlines or doing research on this subject. Also, we can only have one member of a household in our meeting, so please do not bring other family members or friends with you to the discussion. If for some reason you find you are not able to attend, or if you need additional directions, please call me to let me know as soon as possible. My office phone number is (615) 974-3927.
I look forward to seeing you on September 22.

Sincerely,

Brian N. Clark
Forum Facilitator

Figure A-2. Sample letter sent to participants in focus groups on public perception of powerline right-of-way management in eastern Tennessee, 1992-1994.

INFORMED CONSENT DOCUMENT

The purpose of this study is to determine how people feel about the management of the cleared areas beneath powerlines, which are often called powerline rights-of-way. The group discussion will last about 1 $^{1}/_{2}$ hours. During that time, you may be shown pictures or slides and asked questions about your reaction to what you see. You will also be asked to share your feelings and concerns about powerline rights-of-way. A questionnaire will be given to ask you some general questions about your background, but it will not contain your name or personal information. The discussion will be audiotaped in order to record everyone's comments. In the unlikely event that you or the group is asked a question you do not feel comfortable discussing, please feel free to not answer that question. Your responses will be confidential.

This study will help us determine what things are liked and disliked about powerline clearings (rights-of-way), and if there are any preferences people have about the way rights-of-way are maintained. Utilities and land management agencies may use this information to better serve their customers.

There are no substantial risks in this discussion group, although it is possible that you may feel uncomfortable at times during the discussion because of what someone else says. Please keep in mind that in this group there are no "right" or "wrong" answers, because we are interested in what each person feels about the topics discussed. Also, you may feel some eye fatigue from viewing the slides or pictures. Please ask if the lights can be adjusted for better viewing.

Your identity will be kept confidential. The audiotapes used will be transcribed later by the investigator, and each participant will be identified on the transcripts as "Respondent 1," "Respondent 2," and so on. Until May 1, 1995, the tapes, transcripts, and questionnaires will be stored in a locked file cabinet in the researcher's office. They will be accessed by the researcher and four University of Tennessee faculty members: Dr. Mark Fly, Dr. David Buehler, Mr. Richard Evans, and Dr. Ken Newton. The materials will be held after May 1, 1995, by Dr. Mark Fly. These materials may be used for educational or research purposes after that time, such as to demonstrate how discussion groups work. Your last name will not be associated with your recorded voice, and your name will not appear on the transcript or on any subsequent publication.

Figure A-3. Informed consent document used in focus groups on public perception of powerline right-of-way management in eastern Tennessee, 1992-1994.

The results of this study will be reported by summarizing comments and the tone of what was said. In some cases, direct quotes may be used to demonstrate a point, but no names will be associated with comments anywhere in the results.

If you have any questions about the research, either now or later, please contact Brian N. Clark, P.O. Box 1071, University of Tennessee, Knoxville, Tennessee 37901-1071, or call (615) 974-3927. Your participation may be terminated if you bring others to the discussion, if your behavior is disruptive to the discussion, if you are under the influence of intoxicating substances, or if too many people come to the discussion. If you decide not to take part in this discussion, or if you wish to leave at any time, you may do so without penalty.

* * * * * * * * * * *

I have read and understand the explanation of this study and agree to participate.

Name _____ Date_____

Signature _____

Figure A-3. (continued)

RELEASE FORM

I give the University of Tennessee and its representatives permission to use the audiotape, transcripts, and results from this discussion group for educational and research purposes. I realize that my name will not be used nor will my name be associated with my responses on the transcript or publications using the results of this discussion.

Name _____ Date _____

Signature _____

Figure A-4. Release form used in focus groups on public perception of powerline right-of-way management in eastern Tennessee, 1992-1994.

Discussion Introduction

Good evening and welcome to our discussion tonight. Thank you for taking the time to join in this talk about powerlines. My name is Brian Clark and, as you all know, I represent the University of Tennessee. I am attempting to find out how people feel about the way powerline clearings are managed. I have invited you to share your perceptions and ideas on this important topic.

You were selected because you all have something in common that is of particular interest to us. You all are from the Knoxville area and have large powerlines crossing your property.

Tonight we will talk about powerlines and subjects related to them. There are no right or wrong answers to our questions, but rather different points of view. Please feel free to share your point of view even if it differs from what others have said.

Before we begin, let me mention some ground rules. This is strictly a research project and there are no sales involved. Please speak up tonight. We're tape-recording the session because we don't want to miss any of your comments. Since I can't write fast enough to record your comments on paper, I will play the tape back tomorrow and transcribe your comments. Only one person should talk at a time, because if several are talking at the same time, the tape will get garbled and we'll miss your comments.

We will be on a first name basis tonight, and in our later reports there will not be any names attached to comments. You may be assured of confidentiality. Keep in mind that we're just as interested in negative comments about a subject as positive comments, and at times the negative comments are the most helpful.

Our session will last about an hour and a half, and we will not be taking a formal break. The rest rooms are just down the hall and refreshments are over near the wall. Feel free to leave the table for either of these or if you wish to stretch, please do so quietly.

Well, let's begin. I've placed name cards on the table in front of you to help us remember each other's names. Let's find out some more about each other by going around the room one at a time. Tell us briefly about your favorite outdoor activity. Just a sentence or two would be great.

Figure A-5. Introduction used in focus groups on public perception of powerline right-of-way management in eastern Tennessee, 1992-1994.

Discussion Guide

Habitat Free Association

1. Using the pen and paper in front of you, describe what kind of picture comes to mind when you hear the words "wildlife habitat." What do you think of when you hear "wildlife habitat?"

Now turn the piece of paper over.

Herbicide Free Association

2. When you hear the word "herbicide", what comes to your mind? Write down a word or sentence to describe what comes to mind...(Pause)...please share what you wrote down.

Preferences Among ROW Cover Types

3. I'd like for you to look at 3 different types of plant growth beneath powerlines and tell me which you like best. We'll call the slides A, B, and C in the order I show them. Please write down A, B, and C on your paper and after seeing the three types of growth in the 3 slides, rank them in order of which you like best. Please focus your attention on the plants beneath the powerlines.

Which one of the kinds of plant growth shown in these slides appeals to you most?

Probe -- what are some things that appealed to you about the slide you ranked highest?

Slide: "Wildlife Habitat." For the purpose of our discussion, we'll define wildlife habitat as "any area used by wild animals in their daily activity or to meet their life requirements"

Slide: "Herbicide." For our discussion tonight, let's define herbicide as "a chemical that's used to kill plants or to control plant growth."

Slide: "Right-of-way." A right-of-way is "a cleared area beneath a powerline." Rights-of-way are usually owned by landowners and managed by the electric utility that owns the powerline going through the right-of-way.

Slides: Transmission rights-of-way examples on slides.

"In order to provide safe and efficient service, electric power utilities have to maintain or control the plants and brush (tall-growing, woody plants or trees) that grow in rights-of-way in order to keep it from growing up into the powerlines."

Figure A-6. Questioning route used in focus groups on public perception of powerline right-of-way management in eastern Tennessee, 1992-1994.

Knowledge of ROW Management Methods

4. What methods do you know of that are used to control the trees and brush that grow beneath powerlines?

Perceptions of Herbicides

5. How would you feel if herbicides were going to be used by utilities to control right-of-way trees and brush?

PROBE - What things do you dislike about the idea?

6. What do you feel are some possible benefits to using herbicides to control ROW brush? Some possible drawbacks?

ROW and Habitat Management

7. Have you ever thought of a powerline ROW as wildlife habitat? If you said yes, what made you think of the ROW that way?

8. How would you feel about herbicides being used by an agency or individual to improve wildlife habitat in an area?

Probe - Do you feel it is acceptable to use herbicides to improve wildlife habitat for some animals?

Government Regulation of Herbicides

10. Are you aware of how an herbicide gets government approval for use?

Probe - Does this review process affect your feeling that herbicides are safe for use?

Statement: EPA Approval Process.

The Environmental Protection Agency, or EPA, is a government organization responsible for regulating chemical use and pollution in the United States. For a chemical to be registered for use in America, it follows this path for approval:

a. From the time a chemical is formed through testing and approval by the EPA, 6-8 years usually pass.
b. Usually $30-50 million or more are spent doing research and filing for registration.
c. It must pass about 120 tests for safety and environmental effects.

11. Does this process affect your opinions toward herbicides or the use of herbicides on ROWs?

Figure A-6. (continued)

Most Important ROW Management Considerations

12. What considerations would you say are the most important to you regarding the maintenance of powerline ROWs?

13. What could a utility do to make their ROW maintenance better or the best it could be?

Perceptions of Tebuthiuron

I'd like to read a statement about a herbicide that is being used or considered for use on ROWs in the Southeast and get your impressions of it. The herbicide's chemical name is tebuthiuron. First, I'll put up a slide which describes the herbicide, then I'll read the statement.

Statement: Tebuthiuron is an herbicide that was registered for use by the Environmental Protection Agency in 1979 that can be used to kill brush on rights-of-way and allow other plants like grasses, wildflowers and other low-growing plants to take the brush's place. It is applied to the soil in small pellets and runs down into the soil when it rains. Tree roots absorb the chemical, which causes leaves to stop producing food for the plant and drop off. The tree then sends energy from the roots to produce new leaves, but since they can't produce food, they are dropped again. This continues until the tree runs out of energy storage in the roots and dies. Tebuthiuron can cause low-growing plants like grasses to die, but they usually grow back quickly.

This herbicide has been given the EPA "caution" rating for use around wildlife and livestock. It is a urea-based chemical; it is easily excreted by animals and does not build up in animal tissues. Also, it stays mostly in the upper couple of feet of soil, so it shouldn't pose a threat to the water supply if used properly.

14. Does this herbicide sound acceptable for treatment of ROW brush?

PROBE - Does it sound o.k. for use in managing wildlife habitat in some places?

Figure A-6. (continued)

Background Questionnaire

The following information is completely voluntary. You may respond to as many of the questions as you like. Your responses are completely confidential and will not be associated with your name.

1. Do you live within a city's limits? (Check one)

   _____ Yes _____ No

2. If so, what city do you live in? _____

3. If not, what county do you live in? _____

4. Do you farm for part of your personal or family income?

   _____ Yes _____ No

5. Gender: ____ Male _____ Female (Check one)

6. Race: (Check one)

   _____ American Indian _____ Asian _____ Black

   _____ Hispanic _____ White _____ Other:_____

7. Age: (Check one)

   _____ 18-24 _____ 40-49 _____ 60-69 _____ 80+

   _____ 25-39 _____ 50-59 _____ 70-79

8. What is the highest level of education you have completed? (Check One)

   ____ Elementary School ____ 1-4 Years of College

   ____ Some High School ____ 4-Year College Diploma

   ____ High School Diploma ____ Some Graduate School

   ____ Some Technical School ____ Graduate Degree

   ____ Technical School Diploma

7. Annual Income: (Check one)

   ____ 0 - $9,999 ____ $50,000 - $59,999
   ____ $10,000 - $19,999 ____ $60,000 - $69,999
   ____ $20,000 - $29,999 ____ $70,000 - $99,000
   ____ $30,000 - $39,999 ____ $100,000 - $199,999
   ____ $40,000 - $49,999 ____ $200,000 +

Figure A-7. Background questionnaire used in focus groups on public perception of powerline right-of-way management in eastern Tennessee, 1992-1994.

VITA

Brian Clark was born in Asheboro, North Carolina, in 1969, and was raised on a small farm near the town. As a youth, he developed a deep appreciation for natural resources through active involvement in the Boy Scouts of America and the Future Farmers of America, and through outdoor recreational activities including hiking, camping, and hunting. Brian graduated from Southwestern Randolph High School in 1987. He received a Bachelor of Science Degree in Forestry and Wildlife from Virginia Tech in December 1992.

Brian's educational and work experiences with universities, agencies, and private sector organizations fostered in him an awareness of the importance of integrating human and wildlife concerns into resource management. He received a Master of Science Degree from the University of Tennessee, Knoxville, in Wildlife and Fisheries Science in May 1995. Brian has committed himself professionally to natural resource stewardship, hopeful that people will enjoy and learn from the wildlife resource for generations to come.