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Restoration of a Limestone Glade and Former Barrens at Fults Hill Prairie Nature Preserve in Southwestern Illinois

by

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Forty-eight 0.01 ha permanent plots with six 1 m^2 nested quadrats were established to compare the effect of three restoration treatments: (a) cut-burn, (b) cut-herbicide and (c) burn, on the vegetation of limestone glade and barrens communities degraded by woody encroachment at Fults Hill Prairie Nature Preserve. Tree diameter, tree, sapling/shrub and regeneration density and cover, herbaceous cover, and flowering culm density were measured before (1994) and after treatment (1995). Detrended Correspondence Analysis (DCA) was used to determine the relationship among plots, herbaceous species cover and treatment effects. Growth rings from stump sections were counted to age cut trees.

In the barrens, tree basal area, density and cover decreased with cutting, but were unaffected by burning, while sapling/shrub density and cover decreased, and regeneration density and herbaceous cover increased with both cutting and burning. In treatments involving cutting, relative dominance of *Quercus prinoides* increased in the overstory, cover of disturbance-related herbaceous species increased, and several prairie species were encountered for the first time. In all treatments, regeneration density of *Rhus aromatica* and woody vines increased, and cover of prominent woodland herbaceous species, such as *Solidago ulmifolia*, *Helianthus divaricatus* and *Muhlenbergia sobolifera*, increased, with the greatest increase in the cut treatments.

In the glade, treatment effects on vegetation were the same as in the barrens. In treatments involving cutting, where the greatest changes in total abundance occurred (except for regeneration density), *Juniperus virginiana* trees and saplings were eliminated, and *Aster oblongifolius* and *Tridens flavus* increased substantially. *Helianthus divaricatus* cover and *Rhus aromatica* regeneration density increased most in treatments involving burning. *Dichanthelium acuminatum* and *Cassia fasciculata* increased substantially in all treatments. *Bouteloua curtipendula* cover and flowering culm density increased most in the burn and cut-herbicide treatments. *Schizachyrium scoparium* cover and flowering culm density changed little due to treatment.

The first ordination axis of DCA separated glades from barrens, while the second axis separated upper barrens plots from lower barrens plots, which had the longest ordination trajectories due to substantial increases in disturbance-related species. Age distribution for barrens hardwoods appeared to indicate a flush of recruitment occurred in the barrens about 40 years ago.

Based on findings, it is recommended that restoration level burning (less than every three years), cutting and herbiciding continue to be used to restore the glade and barrens at Fults Hill Prairie Nature Preserve.

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INTRODUCTION

Woody plant invasion is occurring in many natural forest openings in the Midwest (Steyermark 1940, McInteer 1946, Beilmann and Brenner 1951a, Kimmel and Probasco 1980, Aldrich et al. 1982, Bacone et al. 1983, Nelson 1987, Apfelbaum and Haney 1989, McClain and Anderson 1990, Stritch 1990*b*, Anderson and Schwegman 1991, Heikens 1991, Quarterman et al. 1993, DeSelm 1994, Heikens et al. 1994, Heikens 1998). Factors which may contribute to woody plant invasion include reduction or cessation of fire (McInteer 1946, Kimmel and Probasco 1980, Aldrich et al. 1982, Anderson and Brown 1983, Nelson 1987, Anderson and Schwegman 1991, Guyette and Cutter 1991, Robertson and Heikens 1994, Edgin and Ebinger 1997, Bowles and McBride 1998, Heikens 1998), short or long term climatic change (McInteer 1946, King 1981) and reduction in grazing/browsing due to declines in large herbivore populations (Kimmel and Probasco 1980, Stritch 1990*b*, DeSelm 1994).

In Illinois, many types of communities which are currently experiencing woody plant invasion are already less extensive than they were in the past (Bourne 1820, Engelmann 1862, Vestal 1936, White 1978, White and Kerr 1980, Nyboer 1981, Hutchison et al. 1986, Bowles and McBride 1998). Communities such as barrens and glades, which are relatively small openings surrounded by forest, are undergoing succession to forest, resulting in less community diversity and a loss of habitat for prairie species (White and Kerr 1980, Stritch 1987, Stritch 1990*a*).

Perpetuation of successional communities requires management in the absence of natural disturbance (Kimmel and Probasco 1980, Aldrich et al. 1982, Bacone et al. 1983, McClain and Anderson 1990, Stritch 1990*a*, *b*, Anderson and Schwegman 1991, Tyndall 1992, DeSelm and Murdock 1993, McClain et al. 1993, Tyndall 1994). Common methods used for inhibiting succession and controlling woody species include cutting, burning and selective use of herbicides (DeSelm 1986, Schwegman 1988, INPC 1990*a*, *b*, McClain and Anderson 1990). Several studies in southern Illinois have evaluated the effects of prescribed burning as a management method in natural forest openings undergoing woody succession (Anderson and Schwegman 1971, Bagienski 1979, Stritch 1987, McClain and Anderson 1990, Stritch 1990*a*, *b*, Elsenheimer 1994, Heikens et al. 1994) and the importance of fire in maintaining natural forest openings is widely discussed (Kimmel and Probasco 1980, Bacone et al. 1983, Heikens 1991, Heikens and Robertson 1994, Tyndall 1994). Cutting is often recommended as a management tool, particularly when succession is well advanced (INPC 1990*b*, McClain and Anderson 1990, Stritch 1990*a*, McClain et al. 1993, Heikens et al. 1994, Bowles and McBride 1998). Application of herbicide to cut stumps is recommended to prevent sprouting (Shwegman 1988, INPC 1990*a*). The effects of cutting on woody species are well documented (Burns and Honkala 1990*a*, *b*, INPC 1990*c*, Kays and Canham 1991, Hutchison 1992). The effects of cutting on herbaceous species are less well known.

There is a need for research which compares the ability of various management methods to restore natural communities experiencing woody plant invasion (DeSelm 1986, McClain and Anderson 1990, DeSelm 1994, Heikens 1998). This study examined the effects of prescribed burning, cutting and stump herbiciding on two communities within Fults Hill Prairie Nature Preserve (Fults). Fults is located in Monroe County, Illinois on the Mississippi River bluffs and encompasses ten natural communities, including high quality examples of loess hill prairie and limestone glade which have been managed by prescribed burning since the early 1970's (White 1978, White and Kerr 1980). However, many natural forest openings at Fults, such as barrens and small limestone glades, have not been managed and are losing their original natural character due to woody plant invasion (White and Kerr 1980). This study was designed to compare the ability of three management treatments to control woody plant invasion and restore community character in a previously unmanaged limestone glade and degraded barrens community complex. The research goal was to provide a better understanding of the relative merits of various restoration management methods, as well as to protect and restore additional natural forest openings within the nature preserve as recommended by White and Kerr in their management guidelines for the site (1980).

Objectives

1. To determine and compare the effect of three treatments: (a) cut-burn, (b) cut-herbicide and (c) burn, regarding their ability to increase prairie species cover, diversity and flowering and reduce woody species abundance, as measured by cover, density and tree basal area, within a limestone glade and degraded barrens community complex at Fults Hill Prairie Nature Preserve.
2. To make recommendations for future management of the site based on treatment results.

LITERATURE REVIEW

Origin, Maintenance and Character of Glades

Natural forest openings such as glades and barrens result from a combination of factors including topography, soil, climate, and fire (Kilburn and Warren 1963, Nelson 1987, Stritch 1990*b*, Heikens 1998). In the absence of fire, only the most xeric openings are maintained. More mesic sites convert to forest (White and Kerr 1980, Heikens 1991, Bowles and McBride 1998).

The occurrence of glades is associated with the presence of resistant rock formations which outcrop at or near the soil surface. Glades are usually found on steep south or west-facing slopes (Aldrich et al. 1982, Nelson and Ladd 1983). High irradiance, seasonal temperature and soil moisture extremes, erosion, and frost upheaval typify the harshness of glade conditions (Quarterman 1989, Nelson and Ladd 1983, Quarterman et al. 1993). Plant species which occupy glades must be adapted to these extreme conditions. Members of the Poaceae, Asteraceae and Fabaceae often predominate (Terletzky and Van Auken 1996).

Heikens (1991) characterized southern Illinois limestone glades as grasslands containing scattered *Juniperus virginiana* and/or *Quercus prinoides* and $\geq$10 % prairie species cover with soil depths <10 cm and exposed rock >1 %. White and Madany (1978) described Illinois glade vegetation and ground cover as a patchwork of stunted trees, shrubs, clustered herbs, bare ground, and exposed rock. Dry or xeric conditions prevail. Limestone glades in Illinois are dominated by *Schizachyrium scoparium*, *Bouteloua curtipendula* and *Sorghastrum nutans*. Characteristic limestone glade species include a number of succulents, composites, xerophytes, and/or calciphiles such as *Aster patens*, *Brickellia eupatoriodes*, *Cacalia plantaginea*, *Echinacea pallida*, *Eryngium yuccifolium*, *Juniperus virginiana*, *Manfreda virginica*, *Quercus prinoides*, and *Silphium terebinthinaceum* (White and Madany 1978).

Factors cited in the maintenance of glade openings include thin soil, periodic drought, rockiness, exposure, aspect and topography (Erikson et al. 1942, Aldrich et al. 1982, Quarterman et al. 1993). However, even this complex of factors is not sufficient to prevent woody encroachment on many extant glades without periodic fire as a component (Aldrich et al. 1982, Nelson 1987).

Origin, Maintenance and Character of Barrens

The origin and maintenance of barrens has been attributed to a combination of factors including drought, fire and edaphic conditions. Establishment of barrens during the warmer, drier climate of the Hypsithermal is widely suggested (DeSelm 1994, Heikens and Robertson 1994). Fires set by Native Americans likely contributed to barrens establishment and are the primary mechanism cited for barrens maintenance (Baskin et al. 1994, DeSelm 1994, Heikens and Robertson 1994). Barrens may also result from the presence of droughty and infertile soils (Heikens and Robertson 1994, Homoya 1994). McInteer (1946) suggested that soil and bedrock characteristics contributed to barrens establishment in the Big Barrens region of Kentucky and Tennessee, but noted that conversion of barrens to forest was rapid once climate changed and cultural burning practices ceased. Periodic drought may contribute to barrens maintenance, especially on thin soils (DeSelm 1989, Bartgis 1993). Herbivory by *Bison bison* (bison) and *Cervus elaphus* (elk) is cited as another barrens maintenance factor (DeSelm 1989, Stritch 1990*b*, Heikens and Robertson 1994).

The term barrens has been used to describe a wide variety of forest openings which differ in a number of characteristics. Soil depth, rockiness, relative abundance of grasses, forbs, shrubs, and trees, and topography are just a few of the characteristics which vary among communities described as barrens (Heikens and Robertson 1994, Edgin and Ebinger 1997).

The description of Illinois barrens encompasses a number of diverse communities. Illinois barrens are broadly characterized by the presence of prairie flora occurring beneath a canopy of scattered, stunted oaks (White and Madany 1978, Heikens and Robertson 1994). Canopy cover varies widely, from 10% to 80% (White and Madany 1978). The ground layer may vary from predominantly prairie grasses and forbs, to forest herbs, shrubs, bare ground, or various combinations thereof (White and Madany 1978, Heikens and Robertson 1994). Soil characteristics such as depth, stoniness and productivity also vary (Heikens and Robertson 1994).

White and Madany (1978) further divided Illinois barrens into soil moisture classes. Dry barrens occur on shallow soils and/or exposed slope where trees are stunted and grasses are short. Community dominants are primarily xerophytic grasses and oaks such as *Danthonia spicata, Koeleria macrantha, Schizachyrium scoparium, Quercus marilandica, Q. stellata*, and *Q. velutina*. Characteristic species include *Carya texana, Clitoria mariana* and *Liatris squarrosa.*

On dry-mesic barrens, trees and grasses grow taller on deeper, moister soils. Dominant species are *Danthonia spicata, Schizachyrium scoparium, Sorghastrum nutans, Quercus alba, Q. falcata*, and *Q. velutina*. Characteristic species include *Commandra umbellata, Helianthus mollis* and *Parthenium integrifolium.*

Homoya (1994) noted the wide discrepancy in physiognomic characteristics among barrens and suggested that, rather than relying on physiognomy, barrens communities should be defined based solely on the edaphic conditions of drought and infertility, the presence of which are manifested in barrens vegetation. This definition apparently would exclude barrens in which fire played a major role in shaping and maintaining the community.

Many extant barrens might fit Homoya's criteria, thus explaining their persistence even in the absence of fire. Some barrens, such as those occurring on bedrock, may not require fire for maintenance (Homoya 1994). However, the majority of barrens have resulted from a combination of environmental and anthropogenic factors, and most have rapidly converted to forest following settlement, a phenomenon which is largely attributed to lack of fire (Heikens and Robertson 1994, Edgin and Ebinger 1997, Bowles and McBride 1998). It is believed that, in Illinois, fire maintained barrens prior to settlement (White and Madany 1978).

Woody Plant Invasion and Succession

Woody plant invasion threatens the integrity of natural forest openings. The increase in canopy cover which results from woody plant invasion reduces the amount of light reaching the ground layer. The effect on herbaceous species is a reduction in cover due to shading (McClain and Anderson 1990, Smith and Stubbendieck 1990). Changes in herbaceous species composition also occur. Natural forest openings are ecologically significant, yet are becoming increasingly rare. Many have already been lost or suffered degradation due to human land use practices over the past 200 years such as grazing, fire suppression and clearing for agriculture or settlement (White 1978, Smeins 1985, Stritch 1990*b*, Heikens 1998).

Species which encroach on forest openings vary depending on a number of factors including composition of the opening and the surrounding forest, environmental characteristics of the opening and species' dispersal mechanisms (McClain and Anderson 1990, Bartgis 1993). Woody species which are characteristic of and initially encroach on Fults' limestone glades include *Cornus drummondii*, *Rhus glabra* and *R. aromatica*. These same species commonly invade hill prairies (White and Kerr 1980, McClain and Anderson 1990). As with hill prairies, *C. drummondii* and species of *Sumac* become established at the margins of glades through seed dispersal by birds. Once established, these shrubs form dense thickets which shade out and eventually eliminate prairie plants. The shrubs provide perches for birds which deposit more woody seeds along the glade-thicket margin. In this way, the glade succeeds to shrub thicket, filling in from the edge. As succession proceeds, trees eventually replace the shrubs (McClain and Anderson 1990). Quarterman (1950, 1989) described the successional pattern on the limestone cedar glades of Tennessee, noting that sparse herbs were replaced by shrubs which invaded rock crevices forming thickets. The thickets of *Rhus aromatica*, *Symphoricarpus orbiculatus* and *Forestiera ligustrina* were eventually replaced by glade woods dominated by *Juniperus virginiana*.

Juniperus virginiana is another characteristic glade species which encroaches on Fults' and other (Steyermark 1940, Heikens 1998) limestone glades. Individual trees or tree islands of *J. virginiana* occur within limestone glades (Erickson et al. 1942, Aldrich et al.1982, Maxwell 1987) and *J. virginiana* often borders glades, either as individual trees, in thickets or in adjacent woodlands (Brenner 1942, Beilmann and Brenner 1951a, Aldrich et al. 1982, Guyette and McGinnes 1982, Nelson 1987, Baskin and Baskin 1996, Terletzky and Van Auken 1996). *Juniperus virginiana* can become established on glades and barrens when fire is excluded or where rock outcrops provide some protection from fire (White and Kerr 1980, Guyette and McGinnes 1982, Abrell 1990). Birds are prolific dispersers of *J. virginiana* (Beilmann 1951).

Juniperus virginiana invasion threatens glade integrity. Smith and Stubbendieck (1990) recorded an 85% reduction in light and an 83% reduction in herbaceous biomass under *J. virginiana* as compared to surrounding prairie. Gehring and Bragg (1992) examined the effect of *J. virginiana* on prairie vegetation and found a nonnative, *Poa pratensis*, replaced the dominant prairie grass, *Schizachyrium scoparium*, under *J. virginiana*. They concluded that *J. virginiana* canopy closure would result in the elimination of all prairie species and that prevention of *J. virginiana* establishment was important because removal did not assure rapid reestablishment of prairie plants.

Steyermark (1940) outlined successional stages on exposed limestone in the Missouri Ozarks beginning with an open limestone glade dominated by prairie species followed by a *Juniperus virginiana* subclimax, a *Quercus prinoides* subclimax and finally an *Acer saccharum-Q. alba* climax association. More recently, numerous studies have documented *A. saccharum* encroachment on glades and barrens in Missouri (Heikens 1998).

Limestone glades and barrens are commonly found in close association with each other (Bartgis 1983, DeSelm and Murdock 1993, Quarterman et al. 1993), with barrens often bordering or surrounding glades as they do at Fults (Bacone et al. 1983, DeSelm 1989). The barrens studied at Fults are dominated by large, open-grown *Quercus prinoides* with large open-grown *Juniperus virginiana* also present. Woody species invading the barrens are those typical of Fults' dry and dry-mesic upland forests including *Quercus velutina*, *Q. rubra*, *Fraxinus americana*, and *Acer saccharum*. Similar *Quercus prinoides*-dominated communities located adjacent to limestone glades are described in the literature. Brenner (1942) described a *Q. prinoides-A. saccharum* association occurring downslope from an open glade associes which appears structurally and compositionally similar to the limestone barrens at Fults. Of the 14 woody species listed which dominated or characterized the association, 13 occur in the barrens at Fults. Beilmann and Brenner (1951a) described a *J. virginiana-Q. prinoides* association, intimately linked to bedrock characteristics, lying in a narrow band above and below limestone glades. Nelson (1987) described xeric *Q. prinoides-Q. stellata-J. virginiana* forests and dry *Q. prinoides-Q. alba-A. saccharum* forests occurring in association with limestone glades. Maxwell (1987) listed *Q. prinoides* as the dominant species of rocky limestone woods surrounding glades, as well as a glade invader. Bartgis (1983) distinguished *Q. prinoides-J. virginiana-Cercis canadensis*-dominated glade woodlands from the *J. virginiana*-dominated glades and barrens which they often surrounded.

Structural and compositional variation in barrens communities complicates discussion of barrens succession. DeSelm and Murdock (1993) listed oaks among the common invaders of grassland barrens. Other authors consider a scattered oak overstory as an integral part of the barrens community (White and Madany 1978, Heikens and Robertson 1994). McInteer (1946) listed the 20 most abundant tree species of the Big Barrens region of Kentucky, of which half were oaks and hickories. He accounted for the prevalence of heavy fruited species in the Barrens by explaining that these species were already present as small scattered individuals prior to conversion of the Barrens to forest.

In 1983, Schwegman and Anderson (1986) resurveyed a southern Illinois barrens after 11 years of fire exclusion, prior to which time the barrens was burned four out of five years. The barrens, consisting of a 0.2 ha forest opening along an intermittent creek, occurs in a more mesic location than is typical of most barrens. A comparison of burn (1971) versus fire exclusion (1983) data revealed little increase in tree density (stems/ha), but a substantial increase in basal area from 5.5 to 7.9 m^2/ha. The species with the greatest increase in basal area was *Quercus prinoides* which was not recorded in the tree size class prior to 1983. *Juglans nigra* and *Platanus occidentalis*, the dominant tree species, also increased in basal area. Open habitat shrubs, such as *Salix humilis* declined. Herbaceous species response to burning and fire exclusion varied. Species which increased in frequency with burning but declined in the absence of fire include species of *Cassia* and *Solidago*, *Gaura biennis* and *Stylosanthes biflora*. The latter two species were not recorded prior to burning or after fire cessation. Some woodland species, such as *Chasmanthium latifolium*, which declined with burning, increased in the absence of fire, and other woodland herbs were recorded as present for the first time in 1983. By 1983, two of the five permanent quadrats established in the barrens occurred beneath a forest canopy.

Anderson and Schwegman (1991) again resampled the barrens in 1988, 15 years after burning. Between 1983 and 1988 basal area had increased from 7.9 to 10.2 m^2/ha and tree density increased from 179.5 to 337 stems/ha. Between 1970, after two consecutive years of burning, and 1988, after 15 years without burning, tree species richness in the seedling and sapling strata increased from 6 to 20 species. *Asimina triloba*, *Quercus rubra* and *Liriodendron tulipifera* were recorded as present in the barrens for the first time in 1983. *Fraxinus americana* and *Acer saccharum* were recorded as present in the barrens for the first time in 1988. Prairie grasses and forbs continued to decline in frequency, some even disappearing in the 1988 sample, while woodland herbs continued to increase. Anderson and Schwegman concluded that, in the absence of fire, the barrens would succeed to a closed canopy forest dominated by the mesic species which had recently invaded the site.

Management

Introduction.

Natural areas preservation often requires more than just protection. For example, subclimax communities may require restoration and maintenance to ensure perpetuation (Kimmel and Probasco 1980, Aldrich et al. 1982, Bacone et al. 1983, McClain and Anderson 1990, Stritch 1990*a*, *b*, Anderson and Schwegman 1991, Tyndall 1992, DeSelm and Murdock 1993, McClain et al. 1993, Tyndall 1994, Bowles and McBride 1998). Maintenance, through imitation of the historical disturbance regime, may suffice to perpetuate a subclimax community which has undergone minimal woody plant invasion. However, if woody plant invasion is extensive, restoration may be required to reproduce community structure and species composition and diversity.

Prescribed burning, cutting of woody species and the selective use of herbicides are common methods used in restoration management (Bacone et al. 1983, Kimmel and Probasco 1980, Aldrich et al. 1982, Schwegman 1988, McClain and Anderson 1990, Stritch 1990*a*, *b*, Anderson and Schwegman 1991, Guyette and Cutter 1991, Tyndall 1992, McClain et al. 1993, Heikens et al. 1994, Robertson and Heikens 1994, Tyndall 1994, Bowles and McBride 1998). The uses, limitations and effects on vegetation of each method are discussed in turn.

Prescribed burning.

Prescribed burning most closely replicates the natural disturbance processes which operated in communities historically maintained by fire. Because of this, prescribed burning is often considered the preferred method for controlling woody plant invasion in fire-maintained communities (Schwegman 1988).

The success of prescribed burning as a restoration method depends on a number of factors, such as the stage of succession a community has reached. In general, woody invaders are usually more mesic and less fire-tolerant than species of natural forest openings. Under conditions of recent invasion, where woody invaders are seedling and sapling size, prescribed burning alone may succeed in restoring the character of the natural forest opening. When mesic succession is advanced, however, ground cover is reduced by shading, fire no longer carries easily through the community and fire alone is usually not sufficient to restore community character. Another factor to consider to maximize fire effectiveness is the implementation of appropriate fire frequency. Repeated burning may be necessary to restore a community, but annual burning may not be feasible on thin-soiled, sparsely vegetated slopes. On the other hand, burning too infrequently may actually increase woody cover due to resprouting. For savanna restoration, Tester (1989) recommended two years of burning followed by two years without burning. He reasoned that a second consecutive fire served to deplete root reserves causing reduced vigor or death in woody species. Two years without fire allowed for the build-up of fuels. Anderson and Schwegman (1991) noted that irregular fire intervals in barrens allowed for the coexistence of species with different responses to fire. Recognizing the less obvious benefits of fire is also important. For example, fire affects nutrient cycling and soil chemistry and may be an important means of returning nutrients to the soil on dry, thin-soiled nutrient-limited sites (Guyette and Cutter 1991). These are just a few of the factors managers should take into account when considering prescribed burning.

In glades, cessation of fire commonly leads to invasion by *Juniperus virginiana* (Steyermark 1940, Kimmel and Probasco 1980, Aldrich et al. 1982, Thom 1993). Reestablishment of a fire regime is an effective management tool for control of *J. virginiana* in glades because this species does not sprout when top-killed (Kimmel and Probasco 1980, Burns and Honkala 1990*a*). Other glade invaders, such as *Rhus glabra* may actually benefit from fire (Shwegman 1988). If fire is to be used as a management tool for control of such species, care should be taken to burn at an effective time of year or fire should be supplemented with other forms of management.

Because many barrens succeed rapidly to forest in the absence of fire, prescribed burning is often used in barrens restoration. Anderson and Schwegman (1971) monitored the effects of two consecutive spring prescribed burns on a southern Illinois barrens. They noted an increase in woody stems of *Cornus amomum*, *Juglans nigra*, and the prairie shrub, *Salix humilus*, as a result of sprouting. *Juniperus virginiana* and *Betula nigra* seedlings were eliminated. *Juniperus virginiana* was the only species to suffer mortality in the tree size class (≥ 3.5 in. dbh). Frequency of *Cassia* spp. and *Solidago* spp. increased markedly. Barrens restoration projects on the Shawnee National Forest of southern Illinois were greatly expanded after the initial spring burn of a sandstone barrens proved highly successful (Stritch 1990*b*). The burn accomplished its objectives of removing established amounts of *Juniperus virginiana*, other invasive woody species, leaf litter, and duff, thus facilitating regeneration of barrens grasses and forbs, including some species which are rare.

Fire is an integral component of many oak communities, such as barrens. Oaks have several features, such as thick bark, vigorous sprouting after top-kill and rot resistance after scarring, that make them more fire-tolerant than other hardwoods (Bordeau 1954, Lorimer 1985). Oak regeneration is largely dependent on stump sprouts and advance regeneration (Ross et al. 1986, Ward 1992). In general, oak seedlings do not contribute significantly to the regeneration of a stand (Lorimer 1985, Ross et al. 1986, Ward 1992). Lorimer (1985) suggests that fire may benefit oaks not by increasing the number of oak seedlings, but by decreasing the number of competing non-oak saplings, thus increasing oak saplings proportionately. Where oaks are competing with less fire-tolerant species, this idea is supported (Niering et al. 1970, Swan 1970).

Prescribed burning has been used experimentally in many types of fire-maintained *Quercus* communities. At the Highland Rim Forest Experiment Station in Tennessee, prescribed burning was used to determine the effects of annual and periodic fires on hardwood regeneration and herbaceous vegetation within a hardwood forest (DeSelm et al. 1974, Thor and Nichols 1974).

The region studied was described as barrens by early travelers and botanists. Burn plots were located in an area known historically to burn annually (DeSelm et al. 1974). Thor and Nichols' study showed an increase of understory stem densities of *Quercus* spp., *Rhus* spp., *Sassafras albidum*, and *Carya* spp. after annual and 5-year burns relative to a control. *Nyssa sylvatica*, *Cornus* spp., *Liquidambar styraciflua*, *Acer rubrum*, and *Ulmus americana* understory stem densities decreased with burning. Nine years of annual winter burning resulted in the development of open, park-like stands of oak. DeSelm et al. (1974) found herbaceous frequencies declined in the control from 58.7 percent in year three (the first year of sampling) to 9.3 percent in year eight in response to increased canopy cover and decreased available light. Declines were seen in all herbaceous categories: grasses, composites, legumes, and other forbs. Herbaceous frequencies did not change between the third and eighth year of burning for annual or periodic treatments.

Kline and McClintock (1993) studied the effects of burning on a dry oak forest (former savanna). They found that each of two consecutive years of burning resulted in decreases in tree density (stems/ha) and basal area (m^2/ha), which was subsequently offset by increases one year after burning. Ground layer diversity, which included herbs, shrubs and tree seedlings, increased for woodland, prairie and exotic species. The greatest increase was in the woodland species, which were predominant. No prairie species were found in the forest prior to burning. After one year of burning, 18 prairie/savanna species were present, but only five persisted a year after the second burn. Kline and McClintock concluded that canopy cover throughout most of the dry oak forest was still too great to provide sufficient light for prairie species. They further concluded that continued burning might slowly decrease tree density by removing saplings and younger trees.

Nuzzo et al. (1996) studied the effect of repeated fires on ground layer composition of a *Quercus velutina*-dominated sand forest in central Illinois, which had not burned for more than 60 years. Vegetation was monitored over a five year period before, during and after three annual burns. Two burn treatments were compared with an unburned control. Prior to burning, woody vegetation dominated the ground layer, ranging from 74 to 88% cover across the three treatments. Forbs were not abundant (4-18%) and graminoids were even less abundant (0.0-0.7%). Herbaceous cover (forbs and graminoids combined) increased significantly to 48-57% after the first burn and to 65-66% after the second burn due to fire, while woody cover was nonsignificantly reduced by approximately 20%. A single species, *Eupatorium rugosum*, a forest herb, accounted for most of the increase in herbaceous cover. Nuzzo et al. concluded that the increase in cover of forest herbs with burning, rather than prairie grasses, sedges and forbs, may be due to the length of time since burning and a concomitant loss of prairie flora in the sand forest community.

In a study on the effects of 13 years of annual prescribed burning on a Minnesota oak savanna, White (1983) compared burned to unburned areas and found: 1) overstory density and basal area was significantly lower in the burned area, 2) shrub cover was absent in the burned area whereas it was 19% in the unburned area, and 3) grass and forb species richness was significantly higher in the burned area. Although results indicated that savanna structure and composition were gradually being restored through annual burning, White expressed doubts that burning alone would be sufficient to remove trees $\geq$ 25 cm dbh.

Cutting.

Cutting is another restoration management method which can be used to remove invading woody species, reduce canopy cover and increase the amount of light reaching the ground layer. Cutting is an effective management tool for controlling *Juniperus virginiana* on limestone glades and barrens, since this species does not sprout if cut beneath the lowest leafy branch (Schwegman 1988). Unlike fire, which leaves standing dead trees, cutting eliminates such perches for birds, which spread woody plant seeds, and allows for removal of woody material from the site. Removing trees reduces excessive fuel loads, thus minimizing "hotspots" if an area is subsequently burned (Abrell 1990). Cutting or girdling may be more effective than fire for eliminating large, well established *J. virginiana* or for controlling thickets of *J. virginiana* with dense canopies and little ground cover. With little fuel present beneath them to carry fire, such trees may not readily burn.

Cutting may be the preferred restoration tool in other similar situations in degraded forest openings, where dense woody vegetation shades the ground, herbaceous ground cover is sparse and fire will not carry. Here, cutting can be used to thin the opening and increase available light. As herbaceous vegetation responds, fuels build up, and fire can be reintroduced as an effective restoration and management tool.

In barrens restoration, cutting is used to control invasive woody species and recreate former community composition and structure. A barrens restoration in the Cretaceous Hills of southern Illinois employed tree and brush cutting to remove a large portion of the woody vegetation (Stritch 1990*a*). *Sassafras albidum, Acer rubrum, A. saccharinum, Liriodendron tulipifera, Fraxinus americana, Juniperus virginiana*, and *Diospyros virginiana* were cut and removed from the site leaving only open-grown oaks species. The goal was to recreate a landscape reminiscent of presettlement conditions.

Cutting and burning are complimentary restoration techniques. Used in conjunction with each other, greater results may be obtained than if either is used alone. In a barrens restoration in southern Illinois' Cretaceous Hills, Stritch (1990a) noted that fire alone did not eliminate woody vegetation as effectively nor did it benefit herbaceous barrens species as much as fire used in conjunction with cutting. Following management, *Asclepias amplexicaulis, A. tuberosa, Liatris squarrosa*, and *Plantanthera lacera* were seen for the first time in the barrens, in the portion where burning was accompanied by cutting. However, similar recovery was not observed in the portion of the barrens which was only burned. Tyndall (1994), in a comparison of the effects of cutting versus cutting and burning in the restoration of a Maryland serpentine barrens, found that more species were affected by cutting and burning than by cutting alone, and that each treatment affected different species. However, *Schizachyrium scoparium*, the community dominant, was unaffected by either treatment. Heikens et al. (1994), after observing that one prescribed burn was insufficient to significantly reduce woody cover or increase prairie herb cover in chert and shale barrens in southwestern Illinois, suggested that cutting in addition to fire might be needed to restore these barrens. Bittner et al. (1994) subsequently verified this by comparing restored (cleared and burned) areas to unrestored (not cleared, but burned) areas within the shale barrens. Between these areas, they found significant differences in cover for five woody and 30 herbaceous species, including *Schizachyrium scoparium* and *Muhlenbergia capillaris*, two barrens indicators, which had >10x more cover in the restored area than in the unrestored area. They concluded that restoration could be accomplished by occasional burning along with canopy removal. Holtz and Howell (1983) found that cutting followed by a spring burn was sufficient to restore a degraded oak barrens where dwarfed prairie plants had persisted under the forest canopy. McClain et al. (1993) recommended both cutting and burning as part of their management guidelines for restoration of a *Quercus macrocarpa*-dominated black-soil savanna in central Illinois, as did Bowles and McBride (1998) for the restoration of a silt-loam oak savanna in northeastern Illinois.

Many woody species sprout after cutting, which may increase rather than decrease stem densities without appropriate follow-up management. For example, *Rhus glabra*, a woody invader of hill prairies and glades, spreads readily from persistent rootstocks and grows rapidly forming dense thickets which shade out prairie plants. A single cutting does little to control *R. glabra*, which readily sprouts. Recutting, cutting and burning, or cutting and herbiciding are typically necessary for *R. glabra* control (Hutchison 1992). In a barrens restoration in southern Illinois, Stritch (1990a) used prescribed fire to control sprouting of invasive woody species following cutting.

<u>Herbiciding.</u>

The selective application of herbicides is another restoration tool which can be used to control woody plant invasion in natural forest openings. The Illinois Department of Natural

Resources currently uses glyphosate or triclopyr per label instructions for the control of woody plants in natural areas (Ballard pers. comm., Heikens et al. 1994). Both herbicides are recommended for cut stump application (INPC 1990*a*). Stump treatment, the application of herbicide to freshly cut stumps through spraying or painting, is an effective means of preventing sprouting in woody species year-round (Dow, no date). To be most effective, it is important to apply the herbicide to the entire cambial layer next to the bark. Adding dye to the herbicide allows assessment of adequate coverage.

The Illinois Nature Preserves Commission provides guidelines for the use of herbicides in natural areas (Schwegman 1988, INPC 1990*a*). Five guiding principals are outlined. First, herbicides should not be used unless necessary. Schwegman cautions against using herbicides simply to speed up the restoration process. Another example of unnecessary use would be for *Juniperus virginiana* control, because this species can be effectively controlled by fire and cutting. All other available restoration tools should be considered first. On the other hand, herbicide use should not be neglected when it is needed. Cutting without herbiciding is a waste of management time and money if no other means of follow-up control is available and heavy sprouting is inevitable. Third, herbicides should be used selectively to target a particular species. This means carefully choosing the right herbicide and applying it at the appropriate time. The Illinois Nature Preserves Commission's vegetation management guidelines give detailed information on application and use of herbicides for a number of exotic and aggressive plants (INPC 1990*c*). Fourth, herbicide impact should be minimized by choosing the least toxic, least persistent herbicide available and using it at the lowest dose possible for effective selective control. Last of all, great care should be taken during herbicide application. Vegetation guidelines for Illinois nature preserves stress the value of choosing restoration methods which mimic natural processes, such as fire, rather than using herbicides. Mechanical restoration methods, such as cutting, are also preferable to herbiciding (INPC 1990*b*).

Selective herbiciding following cutting can be useful in cases of advanced succession where prescribed burning alone cannot restore community structure. Communities may lack adequate fuels to carry a fire of sufficient intensity to kill large trees and dense shrubs or, as a result of altered site conditions, fire may actually be detrimental to non-target plants (White 1983, Anderson and Brown 1986, Schwegman 1988). Cutting alone may not be sufficient to reduce the density of woody invaders. Species prone to sprouting may increase when cut unless cutting is followed by additional control measures such as recutting, burning or stump herbiciding. Although selective herbiciding following cutting assists in the elimination of woody invaders and the restoration of community structure, it does not duplicate many of the processes of natural fire.

All three management tools described above have inherent advantages and disadvantages. Their use and applicability depend on site requirements and restoration goals (White 1983, Schwegman 1988, INPC 1990*a*, *b*, *c*, Hutchison 1992), which may change over time (Nuzzo and Howell 1990). Limitations in manpower, time and money may affect the choice of restoration methods. Restoration may proceed more quickly or effectively if a combination of tools is used (Stritch 1990*a*). Changes in vegetation may vary with variation in restoration methods (White 1983, Tyndall 1994). Throughout the restoration process, treatment effects should be monitored and evaluated in light of the restoration goals, and methodology should be adjusted accordingly (Nuzzo and Howell 1990).

STUDY AREA

Location and General Description

Fults Hill Prairie Nature Preserve (Fults), located within 1 km of the town of Fults in Monroe County, Illinois, was dedicated as an Illinois Nature Preserve in 1970 (INPC 1971) and was designated as a National Natural Landmark in 1986 (McFall 1991; Figure 1). Fults encompasses 215 ha of uplands and is part of the larger 395 ha Fults Hill Prairie - Kidd Lake Marsh State Natural Area (IDNR, no date). The nature preserve represents an outstanding example of the river bluffs and loess hill prairies found along the eastern edge of the Mississippi River floodplain in Monroe and Randolph counties (Schwegman 1969, Ozment 1967). The boundaries of Fults extend approximately 2.4 km along the bluff face and .8 km from the base of the bluff into the rugged upland beyond. The nature preserve is part of the Renault Grant, a French land grant not subject to Public Land Survey methods, and would occupy parts of sections 22, 26, and 27, T. 4 S., R. 10 W. had it been surveyed (White and Kerr 1980).

Natural Division

Fults lies within the Northern Section of the Ozark Natural Division (Schwegman 1973; Figure 2). Principal natural features of the division include upland and floodplain forests, loess hill prairies and bedrock features such as sinkholes, caves and limestone outcrops. The topography of the division is characterized by sinkhole plains, ravines, river bluffs, and floodplains. Sinkhole ponds, creeks and springs provide aquatic habitat. The division contains many plants and animals rare to Illinois because of their Ozarkian, southern and southwestern affinities (Ozment 1967, Schwegman 1973, White and Kerr 1980).

Physiographically, Fults is part of the Salem Plateau of the Ozark uplift (Leighton et al. 1948, Schwegman 1973). The region is underlain by St. Louis and Salem limestone of Mississippian age and the bluffs at Fults are composed of these formations (Weller and Weller 1939). The bluffs overlook a region of the Mississippi River floodplain referred to as the

Figure 1. Portion of Renault 7.5' topographic map showing Fults Hill Prairie Nature Preserve location and boundaries, and study site location within the nature preserve.

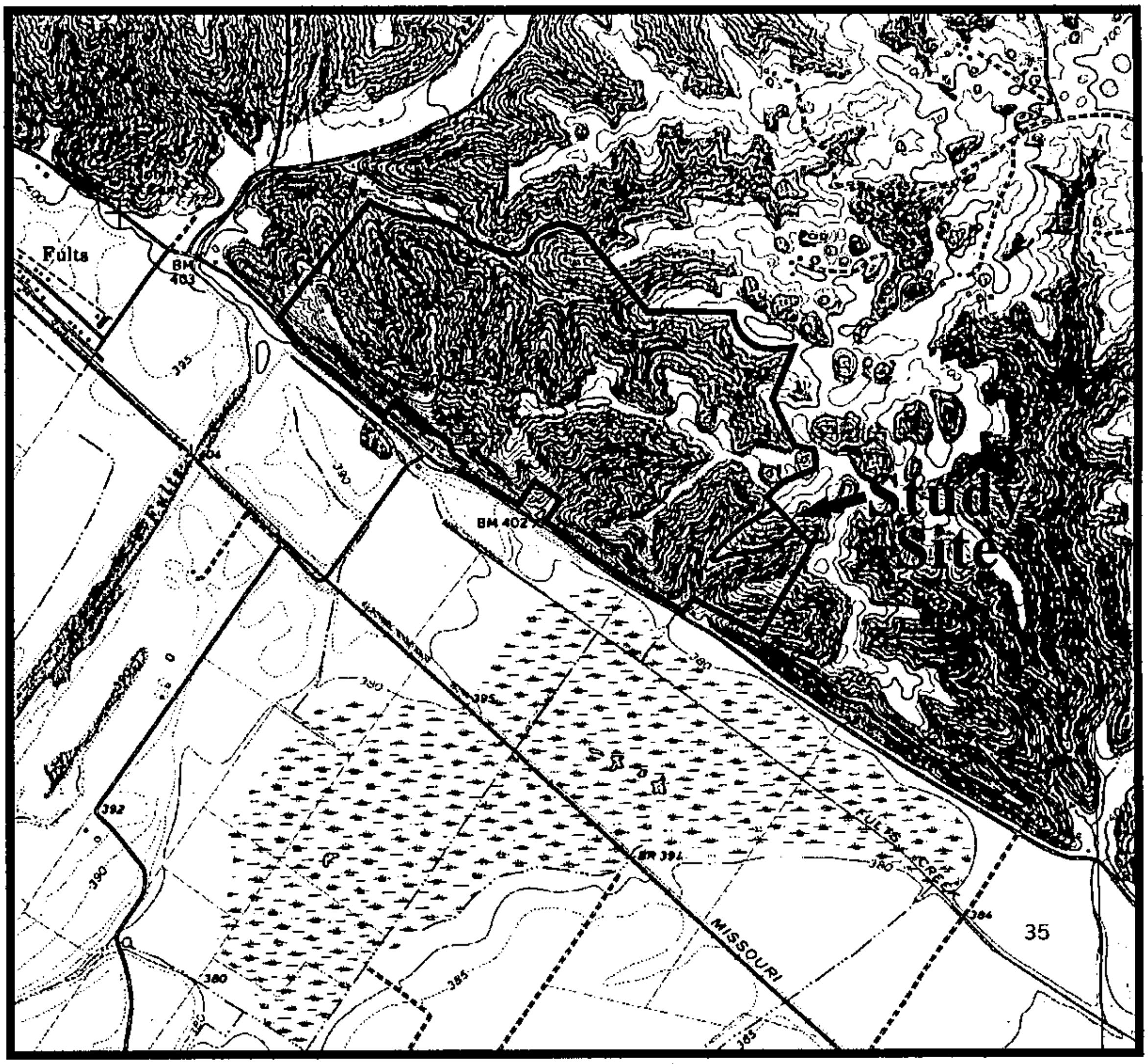
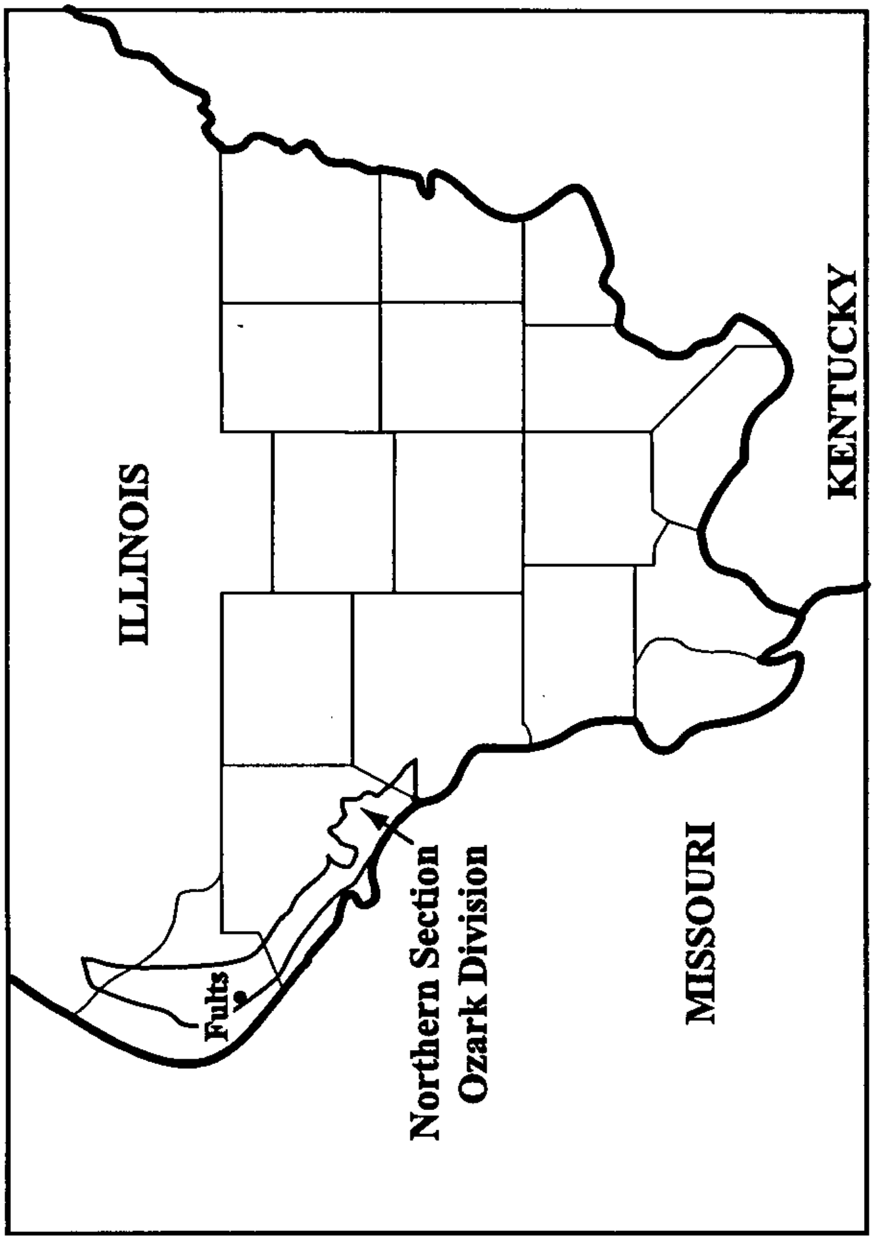

Fults
BM 402
Study site
MISSOURI
35

Figure 2. Location of Fults Hill Prairie Nature Preserve (labeled Fults) within the state of Illinois and the Ozark Natural Division.


ILLINOIS
KENTUCKY
MISSOURI
Fults
Northern Section
Ozark Division

American Bottoms, which lie within the Northern Section of the Lower Mississippi River Bottomland Division (Schwegman 1973). Kidd Lake Marsh, located at the base of the bluff, is a remnant of the extensive marshes that, along with prairie and forest, once covered the river bottoms of this region (Schwegman 1973, White and Kerr 1980). The marsh provides summer habitat for many of the animals that overwinter in the limestone bluffs at Fults (White and Kerr 1980).

Geology and Topography

The most striking topographic features at Fults are the precipitous limestone bluffs which rises 60 to 90 m above the Mississippi River bottomlands (Ozment 1967, Evers and Page 1977, White and Kerr 1980). The bluffs are capped by deep loess deposits upon which are found hill prairies, the most significant natural community within the nature preserve. The deeply dissected uplands have steep slopes and narrow ravines (White and Kerr 1980).

Climate

The nature preserve is situated in southwestern Illinois which has a continental climate characterized by hot, humid summers and wet winters. The region's mean annual temperature is 14° C, with a January mean of 1° C and a July mean of 26° C. The average length of the growing season is 195 days. Average annual precipitation is 99 cm (Schwegman 1973).

Soils

Soils at Fults are developed from the Peorian loess, a silty wind blown deposit derived from the bottomlands during the Wisconsinan glacial period (White and Kerr 1980, USDA 1984). The nature preserve lies just beyond the southwestern edge of the Illinoian glaciation, the most extensive glaciation in the state (Piskin and Bergstrom 1967, Willman and Frye 1970, White and Kerr 1980). Most of the soils of the nature preserve are of the Seaton-Hickory-Eden association, which are steep and very steep, well drained, moderately and slowly permeable, silty and loamy soils formed in loess, glacial till and residuum (USDA 1987). Soils within this association mapped at Fults include Hamburg silt loam, a coarse-silty, mixed (calcareous), mesic Typic Udorthent, found on the bluff crests and Lacrescent flaggy silt loam, a loamy-skeletal, mixed, mesic Typic Hapludoll, occurring on the west-facing sides of bluffs and at their base. In addition, Seaton silt loam, a fine-silty, mixed, mesic Typic Hapludalf, and Eden flaggy silt loam, a fine, mixed, mesic Typic Hapludalf, occur on side slopes. Alford silt loam of the Alford association, a fine-silty, mixed, mesic Typic Hapludalf, is mapped on ridgetops.

Hydrology

Hydrologic features of the site include ephemeral streams, a spring and two sinkhole ponds. The ponds are located at the east edge of the nature preserve and are part of a well-developed sinkhole plain which covers most of Monroe County (Schwegman 1973, White and Kerr 1980). The ponds and spring represent the only permanent surface waters in the nature preserve. The ephemeral nature of the streams is a result of rapid runoff and diversion of water into solution cavities in streambeds (White and Kerr 1980).

Natural Communities and Vegetation

Ten natural communities occur within the nature preserve including loess hill prairie, limestone cliff, limestone glade, savanna (or barrens), and upland forest (INAI, no date, White and Kerr 1980). Mesic upland forest occurs in protected ravines, on north-facing slopes, around sinkhole ponds, and on mesic talus slopes below the limestone cliffs. Dry-mesic upland forest is found on well-drained, primarily south- and west-facing slopes. Dry upland forest occurs on ridgetops and on upper south- and west-facing slopes. Savanna separates the hill prairie openings or occurs on dry, exposed slopes within the dry-mesic upland forest. This community is succeeding to forest. Loess hill prairie occurs on the exposed slopes of deep loess deposits above limestone cliffs. Limestone glades are found on thin, rocky soil on south- and west-facing slopes and on exposed limestone ledges between hill prairies and limestone cliffs (White and Kerr 1980).

Dry upland forests are dominated by *Quercus alba* and *Q. velutina*, with *Q. stellata*, *Q.*

marilandica and *Carya texana* also in the overstory. Common shrubs are *Cornus drummondii* and *Rhus aromatica*. Common herbaceous species include *Solidago ulmifolia, Monarda bradburiana, Desmodium nudiflorum*, and *D. glutinosum* (White and Kerr 1980).

Downslope, these forests grade into dry-mesic upland forest. *Quercus alba* and *Q. velutina* are still dominant, along with *Q. rubra*. Characteristic shrubs are *Cornus florida* and *Ostrya virginiana*, however, the understory is dominated by *Acer saccharum*, a species more typical of the mesic upland forest, which has increased in abundance due to reduced fire frequency. Characteristic herbaceous species include *Eupatorium rugosum* and *Phryma leptostachya* (White and Kerr 1980).

Dry and dry-mesic savannas were prominent communities at Fults 30 to 40 years ago, prior to woody plant encroachment. Fires formerly maintained an overstory of large open-grown oaks and a ground layer of prairie grasses and forbs. At present, these communities contain a dense understory of *Cornus drummondii, Sassifras albidum* and *Cercis canadensis*, with *Carya* spp., *Fraxinus americana* and a mixture of *Quercus* spp. in the overstory. Prairie plants are restricted to a few small scattered openings. The gradual intergrading that once occurred between hill prairie, savanna and forest is gone (White and Kerr 1980).

Few details are written concerning the vegetation of the savanna at Fults. White and Kerr (1980) note only that the savanna is composed of open-grown oaks over grassland vegetation. The Illinois Natural Areas Inventory lists no occurrence of savanna at Fults, however, it does list the occurrence of dry-mesic barrens (INAI, no date), a subclass of the savanna community class (White and Madany 1978). Once again, though, few details of the plant community are noted, other than it is degraded by woody encroachment. A subsequent management schedule for Fults also mentions the occurrence of dry-mesic barrens (Anderson 1989). Heikens (1991) addressed distinctions between the use of the terms savanna and barrens and recommended the term barrens be used to describe the thin-soiled, rocky natural forest openings found in southern Illinois.

Savannas, as described by White and Kerr (1980) and White and Madany (1978), are composed of a grass-dominated ground layer found beneath large broad-crowned trees. Barrens, as described by White and Madany (1978), are composed of a ground layer of prairie grasses and forbs, with varying amounts of woody vegetation present. Based on location, this natural community appears to more closely fit the description given by White and Madany (1978) of dry-mesic barrens rather than that of savanna, because it occurs along a major river valley. Subsequent discussion of this community will employ the term barrens.

Hill prairies of various sizes and shapes, ranging from small, narrow bands to broad slopes several hectares in size, occur on deep loess above the bluffs at Fults (Ozment 1967). A combination of factors, including fire, has maintained these grasslands in a predominantly forested landscape. Dominant grasses of the hill prairies are *Schizachyrium scoparium*, *Andropogon gerardii*, *Sorghastrum nutans*, and *Bouteloua curtipendula* (White and Kerr 1980). Common or characteristic forbs include *Dalea purpurea*, *D. candida*, *Echinacea simulata*, *Euphorbia corollata*, *Lespedeza capitata*, *Liatris cylindracea*, and *Solidago speciosa*. Some of the prairie species at Fults are more typical of western grasslands (White and Kerr 1980, Heikens 1991).

The limestone glades of Fults are composed of prairie vegetation and shrubs occurring on thin, rocky soil and bedrock outcrops. *Schizachyrium scoparium* and *Bouteloua curtipendula* are the dominant grasses, while *Aster azureus*, *Brickellia eupatorioides*, *Dalea purpurea*, *Lespedeza capitata*, *Manfreda virginica*, *Rudbeckia missouriensis*, and *Solidago nemoralis* are common forbs (White and Kerr 1980, Heikens 1991). Many of the forbs characteristic of the narrow cliff-edge glades are rare in Illinois including *Euphorbia spathulata*, *Galium virgatum*, *Heliotropium tenellum*, and *Mentzelia oligosperma* (Ozment 1967, White and Kerr 1980). These species are not commonly found in the larger glades of south- and west-facing slopes (Heikens 1991). *Juniperus virginiana*, *Rhus aromatica* and *Cornus drummondii* are characteristic glade shrubs (White and Kerr 1980). *Juniperus virginiana*, in particular, occurs on outcropping limestone where it is afforded some protection from fire (White and Kerr 1980). The abundance of woody vegetation depends on several factors including glade size and management practices. Larger glades are less susceptible to woody encroachment and are kept open by prescribed burning (White and Kerr 1980, Heikens 1991). Smaller glades are more susceptible to woody encroachment and most are not currently managed (White and Kerr 1980).

Endangered, Threatened and Rare Species

The diversity of communities at Fults provides favorable habitat for a number of plants which are endangered in Illinois. Three species of Illinois endangered plants, *Draba cuneifolia*, *Euphorbia spathulata* and *Galium virgatum*, are known only from limestone ledges at Fults. Other Illinois endangered species occurring at Fults include *Bumelia lanuginosa*, *Heliotropium tenellum*, *Hexalectris spicata*, and *Rudbeckia missouriensis*. Illinois endangered *Panicum longifolium* was collected from a limestone ledge in a wooded ravine at Fults in 1962. Recent attempts to relocate it have been unsuccessful (Herkert 1991).

Fults also provides habitat for several species of animals which have limited distributions in Illinois. These include *Gastrophryne carolinensis* (narrow-mouthed toad), *Masticophia flagellum* (coachwhip), *Tantilla gracilis* (flatheaded snake), *Elaphe guttata emoryi* (great plains rat snake), *Crotalus horridus* (timber rattlesnake), and *Centrurus carolinianus* (prairie scorpion; Ozment 1967, IESPB 1994). *Masticophia flagellum*, *Elaphe guttata emoryi* and *Crotalus horridus* are threatened in Illinois (Herkert 1992, IESPB 1994). *Centrurus carolinianus* is restricted in Illinois to the hill prairies and talus slopes at Fults (Ozment 1967).

Study Site

The study site lies at the east end of Fults Hill Prairie Nature Preserve (Figure 1). The limestone glade portion of the study site consists of two long narrow openings which run parallel to each other along a south facing slope, occurring on thin-soiled, rocky, level ground between outcropping limestone bedrock shelves. The glade vegetation is patchy in distribution, with prairie vegetation interspersed with thickets of *Juniperus virginiana* and species of *Rhus*. The dominant grasses of the glade are *Schizachyrium scoparium* and *Bouteloua curtipendula*. *Aster oblongifolius* is a common forb, while *Rudbeckia missouriensis, Galium virgatum, Allium stellatum*, and *Manfreda virginica* are characteristic forbs. *Juniperus virginiana, Cornus drummondii* and *Rhus aromatica* are considered characteristic trees and shrubs of the glade community (White and Kerr 1980), however, these species, along with *Rhus copallina*, have greatly reduced the size of the glade openings. Shelves of outcropping limestone covered in a dense growth of *J. virginiana* separate the two glade openings from the surrounding barrens.

Between the upper and lower glade and below the lower glade, on the steeper portions of the slope, is the barrens portion of the study site. This community was once more open as evidenced by the large open-grown *Quercus prinoides* and large, often dead, *J. virginiana* in the overstory and the few small patches of prairie vegetation which still remain. The community, however, is in an advanced stage of succession and now contains species characteristic of both dry and dry-mesic upland forest. Among the large open-grown trees are numerous smaller stems of *Q. rubra, Carya texana, Fraxinus americana*, and *Acer saccharum* which have grown into the overstory. Common understory trees are *J. virginiana* and *Cornus drummondii*. *Rhus aromatica* is a common ground layer shrub. *Acer saccharum* is also abundant in the understory and ground layer, particularly on the lower and more protected portions of the slope, where herbaceous species cover and diversity is much reduced. The herbaceous layer is composed of species common to dry upland forest including *Solidago ulmifolia, Muhlenbergia sobolifera, Monarda bradburiana*, and *Desmodium glutinosum*. The barrens soil is very rocky, with scattered rock fragments and small rock outcrops. *Fraxinus quadrangulata, Ptelea trifoliata* and *Bumelia lanuginosa* are occasional trees and shrubs of the glade and barrens.

Natural and anthropogenic disturbances known to have occurred within the glade and barrens include periodic fire, selective cutting, quarrying, and a windstorm. Fire is presumed to have been a major factor responsible for maintaining the glade and barrens community mosaic. Large open-grown *Quercus prinoides* and *Juniperus virginiana* within the barrens show evidence of past fire. Many of the *Q. prinoides* have fire scarred trunks and many standing dead and down *J. virginiana* have charred trunks. Thickets of young, relatively even-aged *J. virginiana* in and around the glade are thought to have developed with the cessation of fire. Francis Heller, an adjacent landowner, spoke of a wild fire which swept through the study site during a dry November in 1953 or 1954 (pers. comm.). The fire spread from the bottomlands where sparks from a passing train ignited Kidd Lake Marsh. Mr. Heller also mentioned that burning of adjacent farm fields in the 1930's resulted in another fire on the study site. The conspicuous absence of *Quercus alba* within the barrens may be due to selective logging of the site in 1938 for railroad ties (Heller pers. comm.). Quarrying occurred on the study site as recently as the 1930's, with limestone being quarried from two locations in the upper glade (Heller pers. comm.). One quarry left a disturbed depression which eventually filled in with *J. virginiana*, while the second left a bare rock shelf. Both locations are backed by an exposed limestone face. A windstorm in the summer of 1995 felled several large trees on the study site. The storm's effects were visible for many kilometers along the forested slopes in and around Fults.

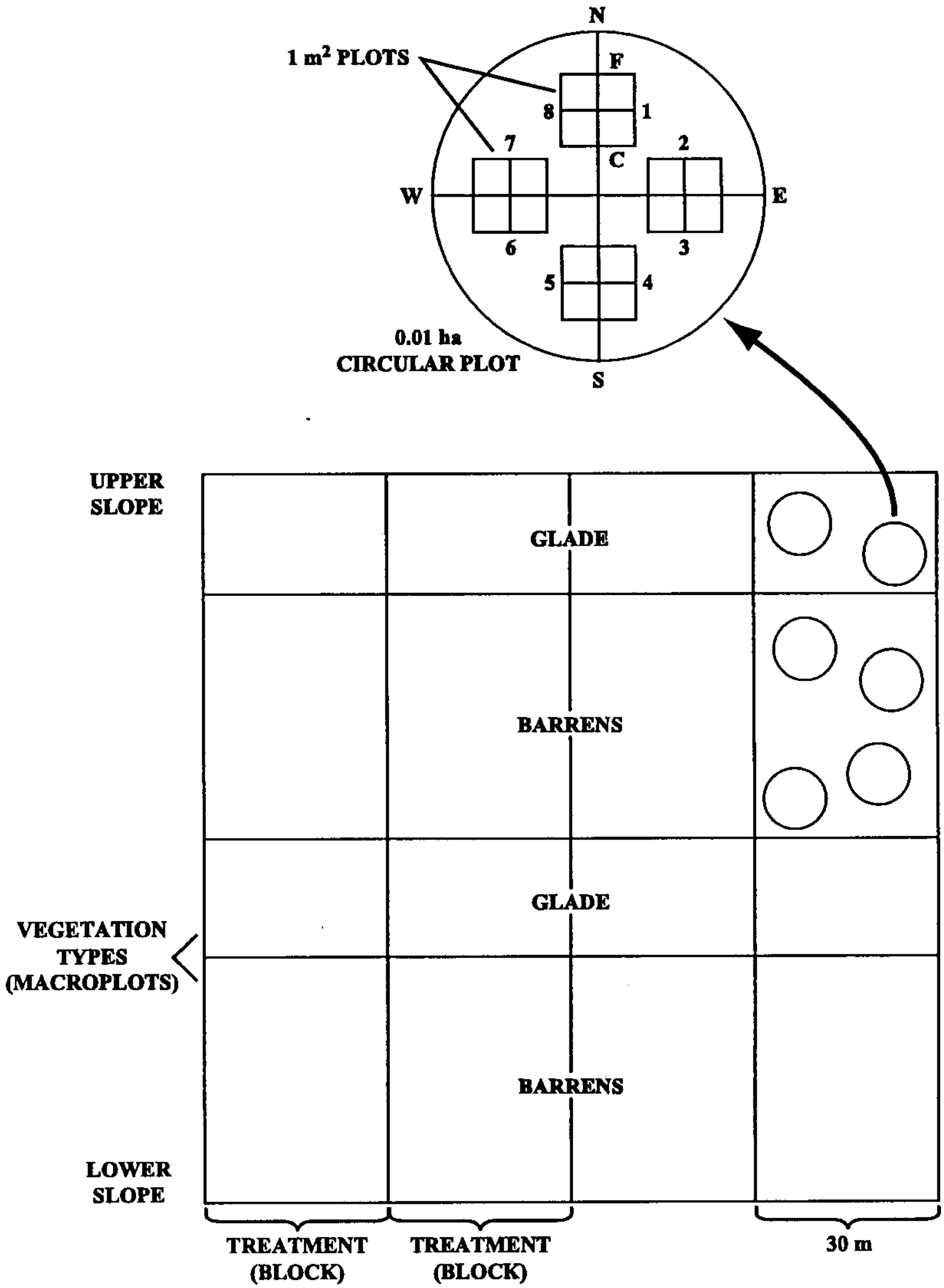
METHODS

Plot Location

Four blocks were permanently established (marked with ½" rebar) within the limestone glade and barrens (Figure 3), each block representing one of three treatments: (a) cut-herbicide: selected invasive species (e.g., *Acer saccharum, Fraxinus americana, Juniperus virginiana, Cornus drummondii, Sumac* spp.) cut followed by herbiciding of deciduous species' stumps, (b) cut-burn: selected invasive species cut followed by a prescribed burn or (c) burn: prescribed burned, or (d) a control: no management. Block width was 30 m, while block length varied as slope length varied. Treatments were not randomly assigned to blocks due to variation in abundance of prairie vegetation across the glade and barrens. The control and the burn treatment were placed in specific blocks, while the cut-burn and cut-herbicide treatments were randomly assigned. This was done to maximize treatment of existing prairie vegetation. Natural boundaries created by outcropping shelves of limestone were used to divide the treatment blocks horizontally into four macroplots based on the two vegetation types, limestone glade and barrens. Macroplot width was 30 m, while the length varied. The glade macroplots were approximately half the length of the barrens macroplots. Macroplot corners were marked with ½" rebar.

Within each macroplot, 0.01 ha circular plots (radius = 5.64 m) were randomly located (Figure 3). The number of plots established per macroplot depended on macroplot size and was unequal but proportional. Two plots were established in each glade macroplot. Four plots were established in each barrens macroplot. The 0.01 ha circular plot centers were permanently marked with ½" rebar. Each plot center was mapped, using the distance in meters and direction in degrees from the marker to each of three trees, to aid in future plot relocation (Appendix 1). Lines were staked from the plot center to the plot edge at cardinal directions to divide the plot into quadrants during sampling.

Figure 3. Sampling design. Close (C) and far (F) 1 m^2 plots were paired and numbered 1-8 clockwise. Close and far indicate the proximity of 1 m^2 plots to 0.01 ha plot center.


N
1 m² PLOTS
F
8
1
7
2
C
W
E
6
3
5
4
0.01 ha
CIRCULAR PLOT
S
UPPER
SLOPE
GLADE
BARRENS
GLADE
VEGETATION
TYPES
(MACROPLOTS)
BARRENS
LOWER
SLOPE
TREATMENT
(BLOCK)
TREATMENT
(BLOCK)
30 m

Woody Vegetation Sampling

Within the 0.01 ha circular plots, overstory trees ≥5 cm diameter at breast height (dbh) were recorded by species and diameter to the nearest 0.1 cm. Saplings/shrubs, defined as understory woody stems <5 cm dbh - ≥1 cm diameter at ground level (dgl), were counted and recorded by species within each 0.01 ha plot. The sapling/shrub size class range was chosen to capture shrub species as well as tree species structure. Woody species data collected within the 0.01 ha plots were recorded by quadrant to facilitate relocation from year to year.

Absolute percent canopy cover of trees and saplings/shrubs was estimated by species within the 0.01 ha circular plots. Tree canopy cover estimates included trees rooted outside the 0.01 ha plot with canopy overhanging the plot. Total canopy cover was estimated for trees independent of species (excluding species overlap).

Regeneration stems (stems <1 cm dgl - ≥5 cm in height) were counted by species and absolute cover of regeneration was estimated by species in six 1 m^2 quadrats nested within the 0.01 ha plots (Figure 3). The six 1 m^2 plots were selected from 16 fixed positions located from 2 to 3 m (close) and from 3 to 4 m (far) from plot center on both sides of the lines marking the four cardinal directions of each plot. Due to the heterogeneity of glade vegetation, plot selection was not random and involved several steps. Close and far plots were paired and numbered one through eight clockwise. Random numbers were generated until six of the eight positions were selected. Random numbers were again generated to determine close or far placement. However, if plots were adjacent to each other on the ground (e.g., plots one and eight), they were juxtaposed, one close, one far. This was done to compensate for the heterogeneity of the glade vegetation, which consisted of prairie grasses and forbs near plot center and shrubs toward the glade edge, to capture a more representative picture of the glade. The selected locations of the 1 m^2 plots were mapped and recorded on the herbaceous cover data forms (Appendix 2).

Herbaceous Vegetation and Environmental Variable Sampling

Within the 1 m^2 nested plots, absolute cover of herbaceous species was estimated by species, flowering culm density (stems/m^2) of two prairie grasses, *Schizachyrium scoparium* and *Bouteloua curtipendula*, was counted, and relative cover of litter, moss, bare soil, and exposed rock was estimated by eye. The litter category included standing live vascular vegetation along with standing dead and down vegetation, so that all environmental variables totaled to 100%. The moss category included *Cladina* sp. (reindeer lichen).

Vegetation Sampling and Management

Pre-treatment vegetation sampling began July 8, 1994 and was completed on October 3, 1994. Two or more color slides were taken of each 0.01 ha circular plot, primarily in cardinal directions, to record plot conditions prior to management. Cutting of selected invasive species occurred on October 20 and 21, 1994. Roundup®[1] herbicide was applied per label instructions to stumps of deciduous species in the cut-herbicide treatment block at the time of cutting. Unintentional differences in cutting resulted in more saplings and shrubs being removed from the cut-burn treatment than from the cut-herbicide treatment. Red cedar was cut periodically from October 20, 1994 through March 6, 1995 in the cut-burn and cut-herbicide treatment blocks. Due to time and personnel constraints, only small red cedars (<6 cm dbh) were cut from the upper barrens cut-burn macroplot. Therefore, this macroplot was considered primarily uncut and its plots were grouped with the plots of the burn treatment for purposes of analysis. The cut-burn and burn treatment blocks were prescribe burned on March 10, 1995. Fire intensity and percent of area burned were recorded for each 0.01 ha circular plot, while other burn conditions were obtained from the District Heritage Biologist (pers. comm.; Table 1). Percent of area burned was averaged by treatment within vegetation type for appropriate treatments (Table 1). Fire intensity, expressed as the type and amount of material consumed (i.e., light/top litter only, moderate/litter

[1]Registered trademark for glyphosate.

and some duff, hot/litter and all duff), was the same for all plots (Table 1).

Table 1. Characteristics of prescribed burn conducted March 10, 1995. $n = 4$ for all treatments except barrens burn treatment, where $n = 12$. Standard deviations are in italics.

Characteristics			
Time ignited: 10:40 a.m.			
Burn crew size: six people			
Temperature: 8° C			
Humidity: 43%			
Winds: from the south at 21 kph			
Time out: 1:15 p.m.			
Fire intensity: light/burned top litter only			
Percent of area burned by treatment:		Barrens	Glade
	Burn	39.8 *17.7*	42.2 *17.2*
	Cut-burn	10.0 *7.7*	46.2 *4.8*

Post-treatment vegetation sampling began July 27, 1995 and was completed on September 28, 1995. Two or more color slides were taken of each 0.01 ha circular plot, primarily in cardinal directions, to record plot conditions following management. Slides will be stored with the author.

Plots were revisited throughout the 1996 growing season to identify unknown species. Additional species noted within the boundaries of the study site were also recorded at this time, but were not quantified or used in data analysis. Glade and barrens vegetation species lists were created for the study site (Appendices 3 and 4), with nomenclature following Mohlenbrock (1986). Only those plants not identifiable in the field were collected. Voucher specimens will be deposited with either the Southern Illinois University at Carbondale or the Illinois Natural History Survey herbarium.

Ingrowth Age Determination

Stump sections from cut trees were collected and sanded. Growth rings were counted to determine age and evidence of fire scarring was examined to supplement information about fire history on the site.

Data Analysis

Woody vegetation.

All woody abundance measures estimated by size class (trees, sapling/shrubs and regeneration) were averaged by vegetation type and treatment within vegetation type for 1994 and 1995. Quadrat abundance measures for regeneration density and cover were averaged within 0.01 ha plots prior to further calculations. Diameter breast height (dbh) was used to calculate tree basal area (m^2/ha). Total canopy cover for trees was calculated independent of individual species (excluding species overlap) and as the sum of individual species (including species overlap). All other total cover estimates, whether for vegetation or environmental variables, were calculated by summation.

Herbaceous vegetation.

Total and individual species herbaceous cover and individual species flowering culm density were averaged by 0.01 ha plot first, then by vegetation type and treatment within vegetation type for 1994 and 1995. Richness, evenness, and diversity indices were used to characterize species abundance relationships (Ludwig and Reynolds 1988). DCA (Detrended Correspondence Analysis; Hill and Gauch 1980) in PC-ORD (version 3.17; McCune and Mefford 1995), with corrections suggested by Oksanen and Minchin (1997), was used to determine the relationship among plots, herbaceous species cover and treatment effects. Herbaceous cover matrices for 1994 and 1995 were combined, in order to examine changes in plots in ordination space with treatment. Species with <5 occurrences were dropped. An initial ordination containing all plots was generated. Control plots, which were not affected by treatment, were removed from the final ordination. DCA default options were selected along with the option for rescaling axes.

Environmental variables and ingrowth age.

Litter, moss, bare soil, and exposed rock cover were averaged by 0.01 ha plot first, then by vegetation type and treatment within vegetation type for 1994 and 1995. Frequency distributions for tree ingrowth age were plotted by species by vegetation type. Within the barrens, hardwood species, which had similar distributions, were grouped together. In addition, since only a limited range of size classes was removed from the field, size class distributions for aged trees and all sampled trees were graphed together to show the range of stem sizes aged and their distribution relative to what occurred on the site. Time limitations prevented the aging of trees in the larger size classes.

Savannas, as described by White and Kerr (1980) and White and Madany (1978), are composed of a grass-dominated ground layer found beneath large broad-crowned trees. Barrens, as described by White and Madany (1978), are composed of a ground layer of prairie grasses and forbs, with varying amounts of woody vegetation present. Based on location, this natural community appears to more closely fit the description given by White and Madany (1978) of dry-mesic barrens rather than that of savanna, because it occurs along a major river valley. Subsequent discussion of this community will employ the term barrens.

Hill prairies of various sizes and shapes, ranging from small, narrow bands to broad slopes several hectares in size, occur on deep loess above the bluffs at Fults (Ozment 1967). A combination of factors, including fire, has maintained these grasslands in a predominantly forested landscape. Dominant grasses of the hill prairies are *Schizachyrium scoparium*, *Andropogon gerardii*, *Sorghastrum nutans*, and *Bouteloua curtipendula* (White and Kerr 1980). Common or characteristic forbs include *Dalea purpurea*, *D. candida*, *Echinacea simulata*, *Euphorbia corollata*, *Lespedeza capitata*, *Liatris cylindracea*, and *Solidago speciosa*. Some of the prairie species at Fults are more typical of western grasslands (White and Kerr 1980, Heikens 1991).

The limestone glades of Fults are composed of prairie vegetation and shrubs occurring on thin, rocky soil and bedrock outcrops. *Schizachyrium scoparium* and *Bouteloua curtipendula* are the dominant grasses, while *Aster azureus*, *Brickellia eupatorioides*, *Dalea purpurea*, *Lespedeza capitata*, *Manfreda virginica*, *Rudbeckia missouriensis*, and *Solidago nemoralis* are common forbs (White and Kerr 1980, Heikens 1991). Many of the forbs characteristic of the narrow cliff-edge glades are rare in Illinois including *Euphorbia spathulata*, *Galium virgatum*, *Heliotropium tenellum*, and *Mentzelia oligosperma* (Ozment 1967, White and Kerr 1980). These species are not commonly found in the larger glades of south- and west-facing slopes (Heikens 1991). *Juniperus virginiana*, *Rhus aromatica* and *Cornus drummondii* are characteristic glade shrubs (White and Kerr 1980). *Juniperus virginiana*, in particular, occurs on outcropping limestone where it is afforded some protection from fire (White and Kerr 1980). The abundance of woody vegetation depends on several factors including glade size and management practices. Larger glades are less susceptible to woody encroachment and are kept open by prescribed burning (White and Kerr 1980, Heikens 1991). Smaller glades are more susceptible to woody encroachment and most are not currently managed (White and Kerr 1980).

Endangered, Threatened and Rare Species

The diversity of communities at Fults provides favorable habitat for a number of plants which are endangered in Illinois. Three species of Illinois endangered plants, *Draba cuneifolia*, *Euphorbia spathulata* and *Galium virgatum*, are known only from limestone ledges at Fults. Other Illinois endangered species occurring at Fults include *Bumelia lanuginosa*, *Heliotropium tenellum*, *Hexalectris spicata*, and *Rudbeckia missouriensis*. Illinois endangered *Panicum longifolium* was collected from a limestone ledge in a wooded ravine at Fults in 1962. Recent attempts to relocate it have been unsuccessful (Herkert 1991).

Fults also provides habitat for several species of animals which have limited distributions in Illinois. These include *Gastrophryne carolinensis* (narrow-mouthed toad), *Masticophia flagellum* (coachwhip), *Tantilla gracilis* (flatheaded snake), *Elaphe guttata emoryi* (great plains rat snake), *Crotalus horridus* (timber rattlesnake), and *Centrurus carolinianus* (prairie scorpion; Ozment 1967, IESPB 1994). *Masticophia flagellum*, *Elaphe guttata emoryi* and *Crotalus horridus* are threatened in Illinois (Herkert 1992, IESPB 1994). *Centrurus carolinianus* is restricted in Illinois to the hill prairies and talus slopes at Fults (Ozment 1967).

Study Site

The study site lies at the east end of Fults Hill Prairie Nature Preserve (Figure 1). The limestone glade portion of the study site consists of two long narrow openings which run parallel to each other along a south facing slope, occurring on thin-soiled, rocky, level ground between outcropping limestone bedrock shelves. The glade vegetation is patchy in distribution, with prairie vegetation interspersed with thickets of *Juniperus virginiana* and species of *Rhus*. The dominant grasses of the glade are *Schizachyrium scoparium* and *Bouteloua curtipendula*. *Aster oblongifolius* is a common forb, while *Rudbeckia missouriensis, Galium virgatum, Allium stellatum*, and *Manfreda virginica* are characteristic forbs. *Juniperus virginiana*, *Cornus drummondii* and *Rhus aromatica* are considered characteristic trees and shrubs of the glade community (White and Kerr 1980), however, these species, along with *Rhus copallina*, have greatly reduced the size of the glade openings. Shelves of outcropping limestone covered in a dense growth of *J. virginiana* separate the two glade openings from the surrounding barrens.

Between the upper and lower glade and below the lower glade, on the steeper portions of the slope, is the barrens portion of the study site. This community was once more open as evidenced by the large open-grown *Quercus prinoides* and large, often dead, *J. virginiana* in the overstory and the few small patches of prairie vegetation which still remain. The community, however, is in an advanced stage of succession and now contains species characteristic of both dry and dry-mesic upland forest. Among the large open-grown trees are numerous smaller stems of *Q. rubra*, *Carya texana*, *Fraxinus americana*, and *Acer saccharum* which have grown into the overstory. Common understory trees are *J. virginiana* and *Cornus drummondii*. *Rhus aromatica* is a common ground layer shrub. *Acer saccharum* is also abundant in the understory and ground layer, particularly on the lower and more protected portions of the slope, where herbaceous species cover and diversity is much reduced. The herbaceous layer is composed of species common to dry upland forest including *Solidago ulmifolia*, *Muhlenbergia sobolifera*, *Monarda bradburiana*, and *Desmodium glutinosum*. The barrens soil is very rocky, with scattered rock fragments and small rock outcrops. *Fraxinus quadrangulata*, *Ptelea trifoliata* and *Bumelia lanuginosa* are occasional trees and shrubs of the glade and barrens.

Natural and anthropogenic disturbances known to have occurred within the glade and barrens include periodic fire, selective cutting, quarrying, and a windstorm. Fire is presumed to have been a major factor responsible for maintaining the glade and barrens community mosaic. Large open-grown *Quercus prinoides* and *Juniperus virginiana* within the barrens show evidence of past fire. Many of the *Q. prinoides* have fire scarred trunks and many standing dead and down *J. virginiana* have charred trunks. Thickets of young, relatively even-aged *J. virginiana* in and around the glade are thought to have developed with the cessation of fire. Francis Heller, an adjacent landowner, spoke of a wild fire which swept through the study site during a dry November in 1953 or 1954 (pers. comm.). The fire spread from the bottomlands where sparks from a passing train ignited Kidd Lake Marsh. Mr. Heller also mentioned that burning of adjacent farm fields in the 1930's resulted in another fire on the study site. The conspicuous absence of *Quercus alba* within the barrens may be due to selective logging of the site in 1938 for railroad ties (Heller pers. comm.). Quarrying occurred on the study site as recently as the 1930's, with limestone being quarried from two locations in the upper glade (Heller pers. comm.). One quarry left a disturbed depression which eventually filled in with *J. virginiana*, while the second left a bare rock shelf. Both locations are backed by an exposed limestone face. A windstorm in the summer of 1995 felled several large trees on the study site. The storm's effects were visible for many kilometers along the forested slopes in and around Fults.

RESULTS

Introduction

The results reported here focus on changes in basal area, density and/or cover with treatment for the burn, cut-herbicide and cut-burn treatments. For more information on vegetation conditions prior to and following treatment, refer to the Appendices. No attempt was made to use control variables as covariables due to the heterogeneity of the communities studied. Control variables are reported in tables and figures because they were included in the calculation of overall means. Change in the control can be attributed in part to effects from windthrow and inadvertent cutting.

Woody Vegetation

Barrens: tree size class.

Seventeen tree species occurred in the barrens in 1994 (Table 2; Appendices 5, 6 and 7). This was reduced to 16 species in 1995. Prior to treatment, basal area, density and total cover within the barrens were 25.2 m^2/ha, 1409 stems/ha and 75.6% cover, respectively (Table 2). *Quercus prinoides* was the dominant tree species within the barrens, with basal area, density and cover of 11.9 m^2/ha, 434 stems/ha and 38.9% cover, respectively (Figures 4 and 5; Appendices 8, 9 and 10). *Quercus prinoides* accounted for 47% of tree basal area and >30% of tree density and cover in the barrens and was dominant in all three treatments and the control. Additional species with basal area >1.0 m^2/ha , density >100 stems/ha and cover >8% were *Acer saccharum*, *Fraxinus americana*, *Juniperus virginiana*, and *Quercus rubra*.

Basal area, density and total cover of trees decreased within the barrens from 1994 to 1995 with treatment. Basal area was reduced by 5.3 m^2/ha (21%), density by 440 stems/ha (31%) and total cover by 19.3% (Table 2; Figure 6). The majority of decrease was attributable to the two cut treatments. Differences noted between decreases in total and individual species cover within treatments are indicative of species canopy overlap (Table 2).

Table 2. Mean basal area, density and cover for barrens trees and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Total species cover represents the sum of species cover (including overlap), while total cover excludes species overlap. Standard deviations are in italics.

Variable	Year/Change	Overall n=32	CN n=8	BO n=12	CH n=8	CB n=4
Basal area (m^2/ha)	1994	25.2	27.1	22.8	22.6	33.6
		10.4	*6.3*	*13.5*	*8.3*	*7.7*
	1995	19.9	25.8	22.2	11.6	17.5
		11.8	*5.3*	*12.5*	*8.9*	*17.6*
	Change	-5.3	-1.3	-0.6	-11.0	-16.1
Density (stems/ha)	1994	1409	1600	1258	1463	1375
		475	*678*	*412*	*407*	*222*
	1995	969	1575	1225	238	450
		697	*663*	*429*	*226*	*300*
	Change	-440	-25	-33	-1225	-925
Total cover (%)	1994	75.6	75.8	73.2	73.9	86.2
		8.4	*8.9*	*5.2*	*10.1*	*4.3*
	1995	56.3	72.1	71.4	28.8	34.5
		24.1	*7.4*	*5.7*	*17.9*	*27.5*
	Change	-19.3	-3.7	-1.8	-45.1	-51.7
Total species cover (%)	1994	113.3	121.8	109.7	102.0	130.2
		28.8	*31.5*	*30.6*	*26.6*	*13.5*
	1995	68.1	90.9	87.1	30.1	41.7
		32.8	*13.8*	*14.8*	*18.7*	*38.0*
	Change	-45.2	-30.9	-22.6	-71.9	-88.5
Total number of species (*S*)	1994	17	12	14	13	8
	1995	16	12	14	9	6

Figure 4. Change in basal area for prominent barrens tree species. QUPR = *Quercus prinoides*, ACSA = *Acer saccharum*, QURU = *Quercus rubra*, JUVI = *Juniperus virginiana*, and FRAM = *Fraxinus americana*. P = basal area present at <0.05 m^2/ha.

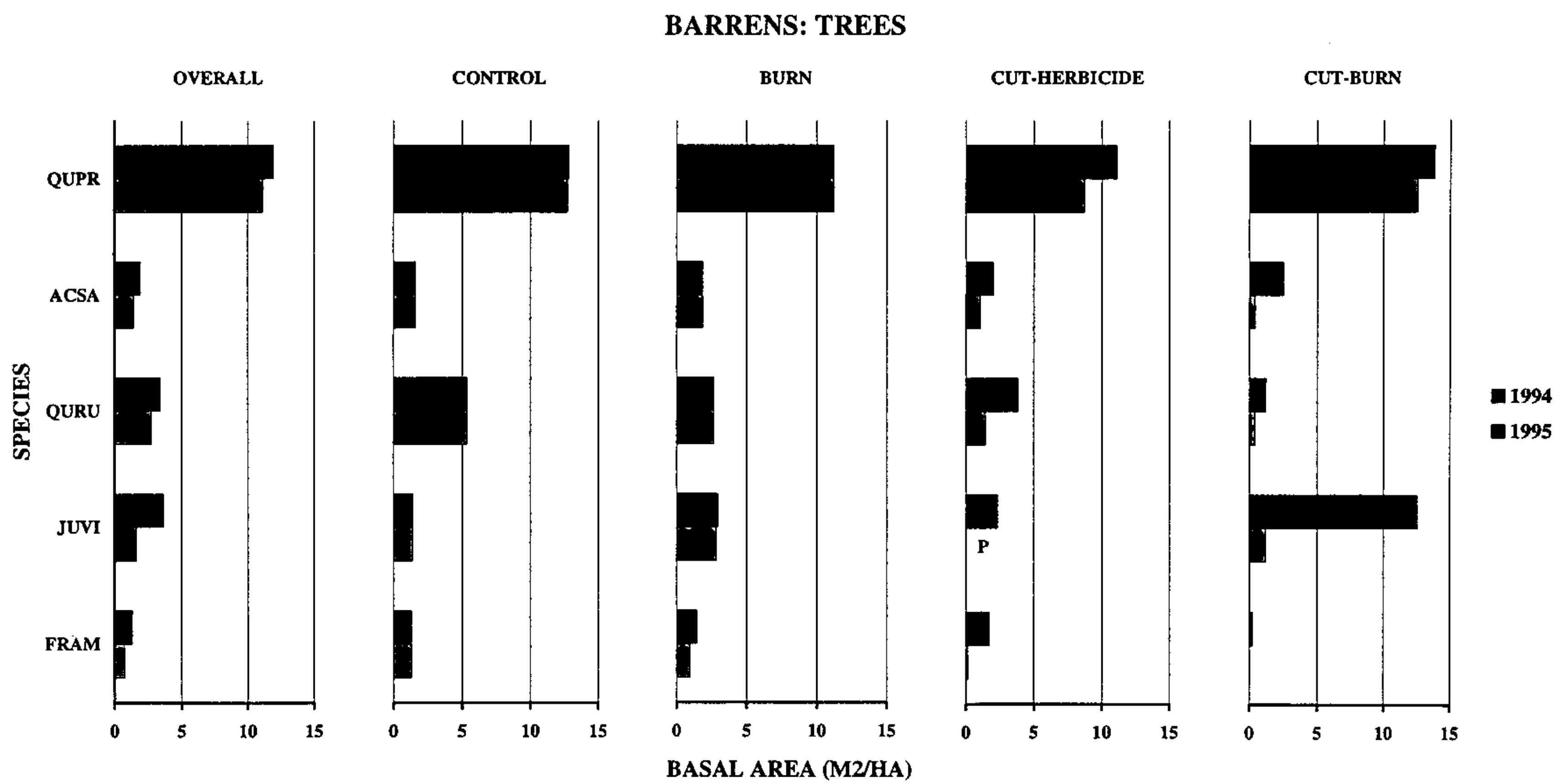

BARRENS: TREES
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
SPECIES
QUPR
ACSA
QURU
JUVI
FRAM
P
0
5
10
15
BASAL AREA (M2/HA)
1994
1995

Figure 5. Change in cover for prominent barrens tree species. QUPR = *Quercus prinoides*, ACSA = *Acer saccharum*, QURU = *Quercus rubra*, JUVI = *Juniperus virginiana*, and FRAM = *Fraxinus americana*.

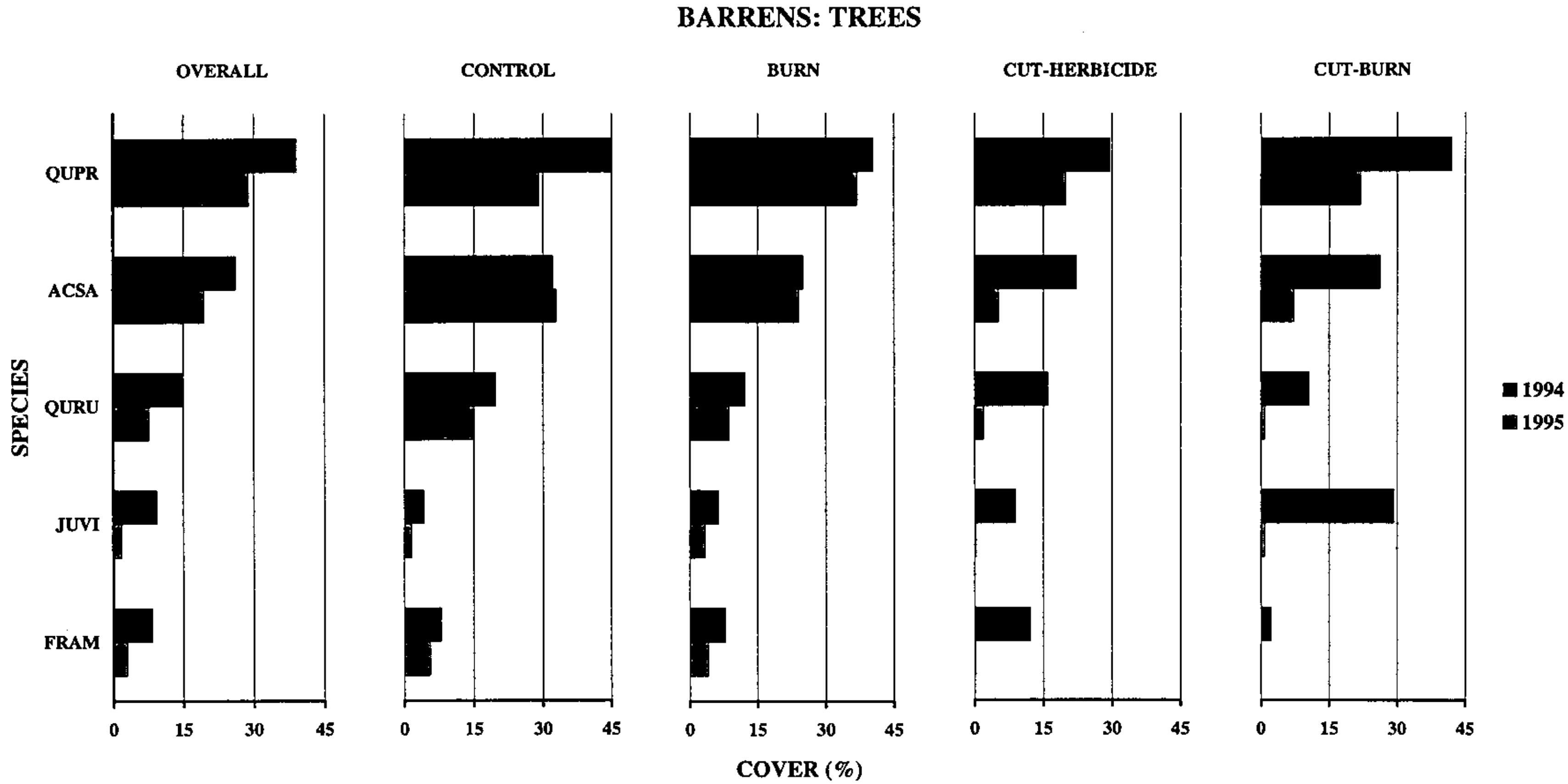
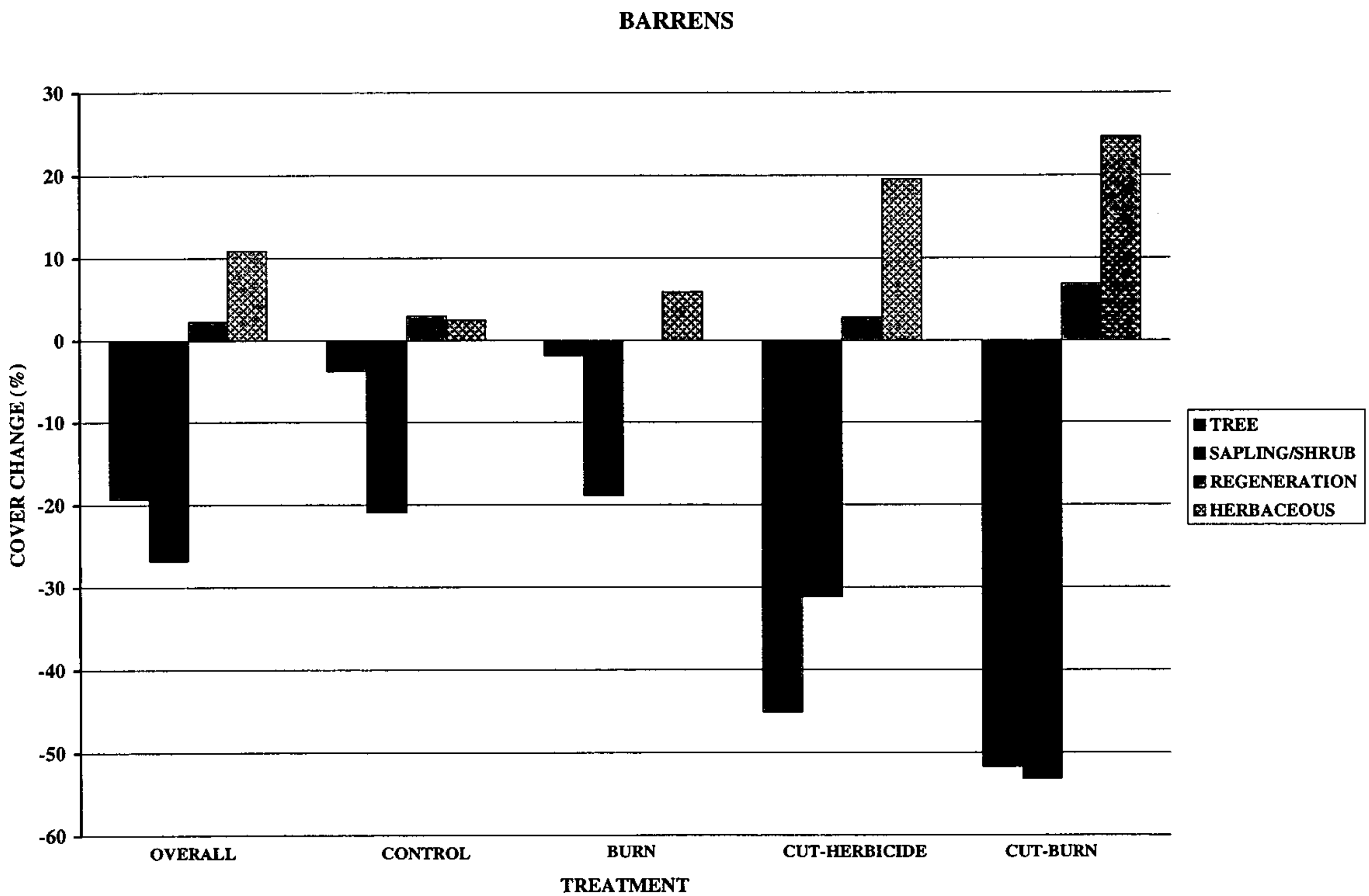

BARRENS: TREES
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
SPECIES
QUPR
ACSA
QURU
JUVI
FRAM
0
15
30
45
COVER (%)
1994
1995

Figure 6. Change in total cover of barrens vegetation.


BARRENS
30
20
10
0
-10
-20
-30
-40
-50
-60
COVER CHANGE (%)
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
TREATMENT
TREE
SAPLING/SHRUB
REGENERATION
HERBACEOUS

In the burn treatment, basal area decreased by 0.6 m^2/ha (3%) and total cover decreased by 1.8% due to windthrow and the cutting of small *J. virginiana* (Table 2; Figure 6). *Fraxinus americana* was reduced in basal area by 0.5 m^2/ha (36%) and in cover by 3.9% (a 50% reduction; Figures 4 and 5). *Juniperus virginiana* cover decreased by 3.0% (a 48% reduction), as this species was intentionally cut in four plots originally intended to be part of the cut-burn treatment.

In the cut-herbicide treatment, basal area was reduced by 11.0 m^2/ha (49%) and total cover was reduced by 45.1% (Table 2; Figures 6, 7 and 8). *Acer saccharum* and *Q. rubra* were reduced by 50% or more in basal area and cover, while *F. americana* and *J. virginiana* were reduced by >94% (Figures 4 and 5).

In the cut-burn treatment, basal area was reduced by 16.1 m^2/ha (48%) and total cover was reduced by 51.7% as a result of cutting (Table 2; Figure 6). *Acer saccharum*, *J. virginiana* and *Q. rubra* were reduced by >66% in basal area and cover, with *J. virginiana* decreasing most, by 11.3 m^2/ha (90%) and 28.4% cover (a 97% reduction; Figures 4 and 5). *Fraxinus americana* was eliminated.

In the barrens, tree basal area, density and total cover decreased with cutting, but were unaffected by burning (Table 2; Figure 6). *Acer saccharum*, *J. virginiana*, *Q. rubra*, and *F. americana* were the species most affected by treatment (Figures 4 and 5; Appendices 8, 9 and 10). *Quercus prinoides* remained the dominant species, most notably in the cut-herbicide and cut-burn treatments, where it accounted for >70% of tree basal area and >50% of tree density and cover following treatment (Figures 4 and 5; Appendices 8, 9 and 10).

Barrens: sapling and shrub size class.

Twenty-eight sapling/shrub species occurred in the barrens in 1994 (Table 3; Appendices 11 and 12). Of these, 24 remained in 1995. Prior to treatment, total sapling/shrub density and total cover within the barrens were 3509 stems/ha and 41.4% cover, respectively (Table 3). No single species was strongly dominant. Three species, *Acer saccharum*, *Cornus drummondii* and

Figure 7. Upper barrens cut-herbicide plot 11 prior to treatment (October 1994).

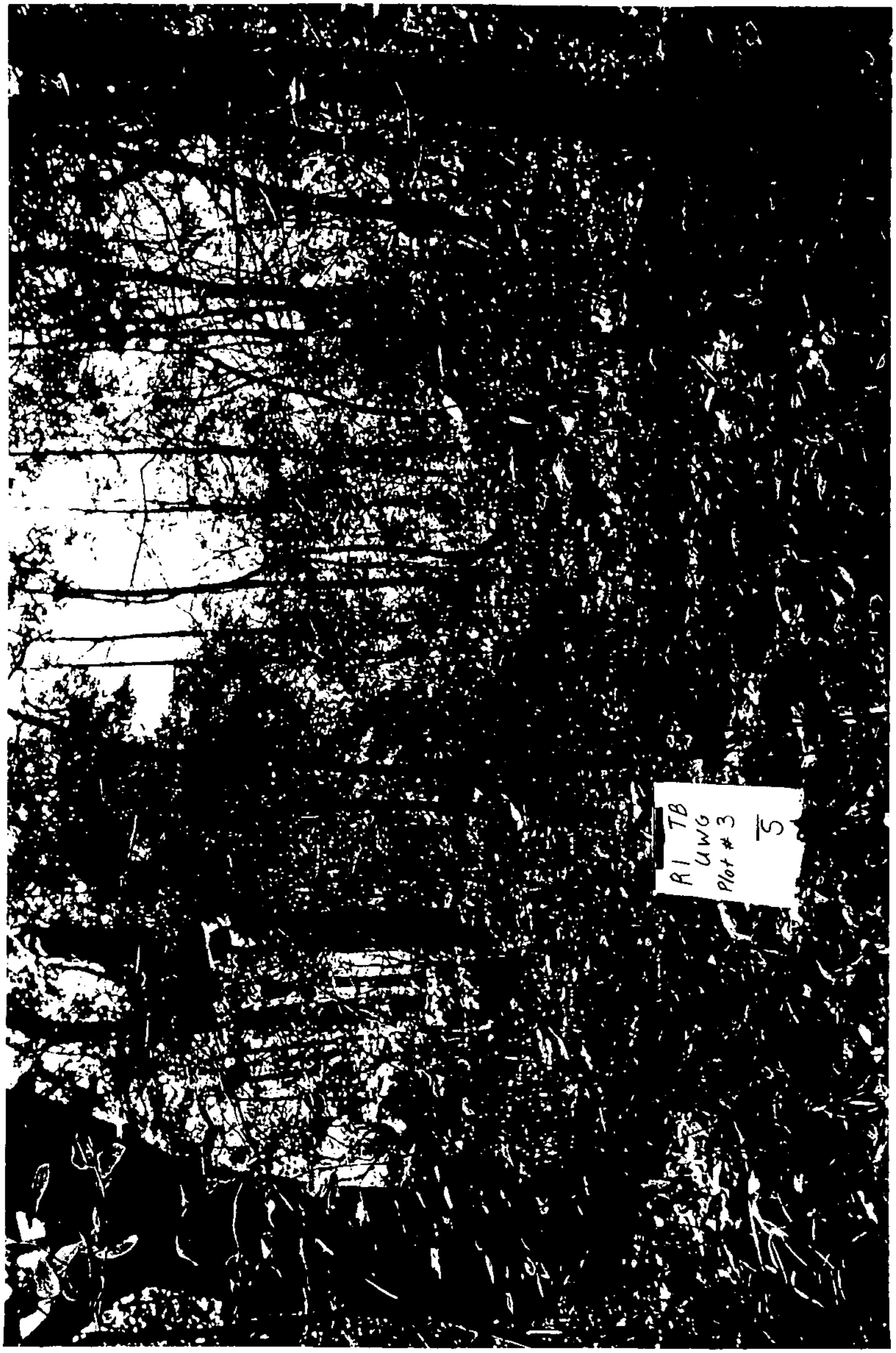

R1 TB
UWG
Plot # 3
5

Figure 8. Upper barrens cut-herbicide plot 11 following treatment (October 4, 1995).


R1 TB
UWG
Plot # 3
10/4/95
5

Juniperus virginiana, were codominant, with densities >500 stems/ha and absolute cover >5.0% (Figures 9 and 10; Appendices 13 and 14).

Table 3. Mean density and cover for barrens saplings/shrubs and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Total species cover represents the sum of species cover (including overlap). Standard deviations are in italics.

Variable	Year/Change	Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
Density (stems/ha)	1994	3509	3375	3583	3562	3450
		1599	*1339*	*1160*	*2244*	*2339*
	1995	1653	2487	1667	1475	300
		1206	*1589*	*695*	*1131*	*82*
	Change	-1856	-888	-1916	-2087	-3150
Total species cover (%)	1994	41.4	42.5	37.5	39.3	54.9
		16.4	*9.0*	*13.9*	*20.4*	*24.6*
	1995	14.6	21.6	18.6	8.1	1.8
		11.0	*13.0*	*8.5*	*5.3*	*1.2*
	Change	-26.8	-20.9	-18.9	-31.2	-53.1
Total number of species (*S*)	1994	28	21	21	21	15
	1995	24	20	18	16	6

Saplings/shrub density and total cover decreased within the barrens from 1994 to 1995 with treatment. Density was reduced by 1856 stems/ha (53%) and total cover was reduced by 26.8% (Table 3; Figure 6). There were substantial decreases in density and total cover in all treatments, increasing in magnitude from the burn, to the cut-herbicide, to the cut-burn treatment, which decreased the most.

In the burn treatment, sapling/shrub density was reduced by 1916 stems/ha (53%) and total cover was reduced by 18.9% primarily in response to burning (Table 3; Figure 6). *Acer saccharum*, *C. drummondii* and *J. virginiana* were reduced in density by >220 stems/ha and in absolute cover by >3.0% (Figures 9 and 10). The greatest reduction of any species was *Juniperus virginiana*, which decreased by 575 stems/ha (85%) and 5.4% cover (a 95% reduction), as this

Figure 9. Change in density for prominent barrens sapling/shrub species. ACSA = *Acer saccharum*, CODR = *Cornus drummondii*, JUVI = *Juniperus virginiana*, COFL = *Cornus florida*, RHCA = *Rhus aromatica*, and VIRU = *Viburnum rufidulum.*

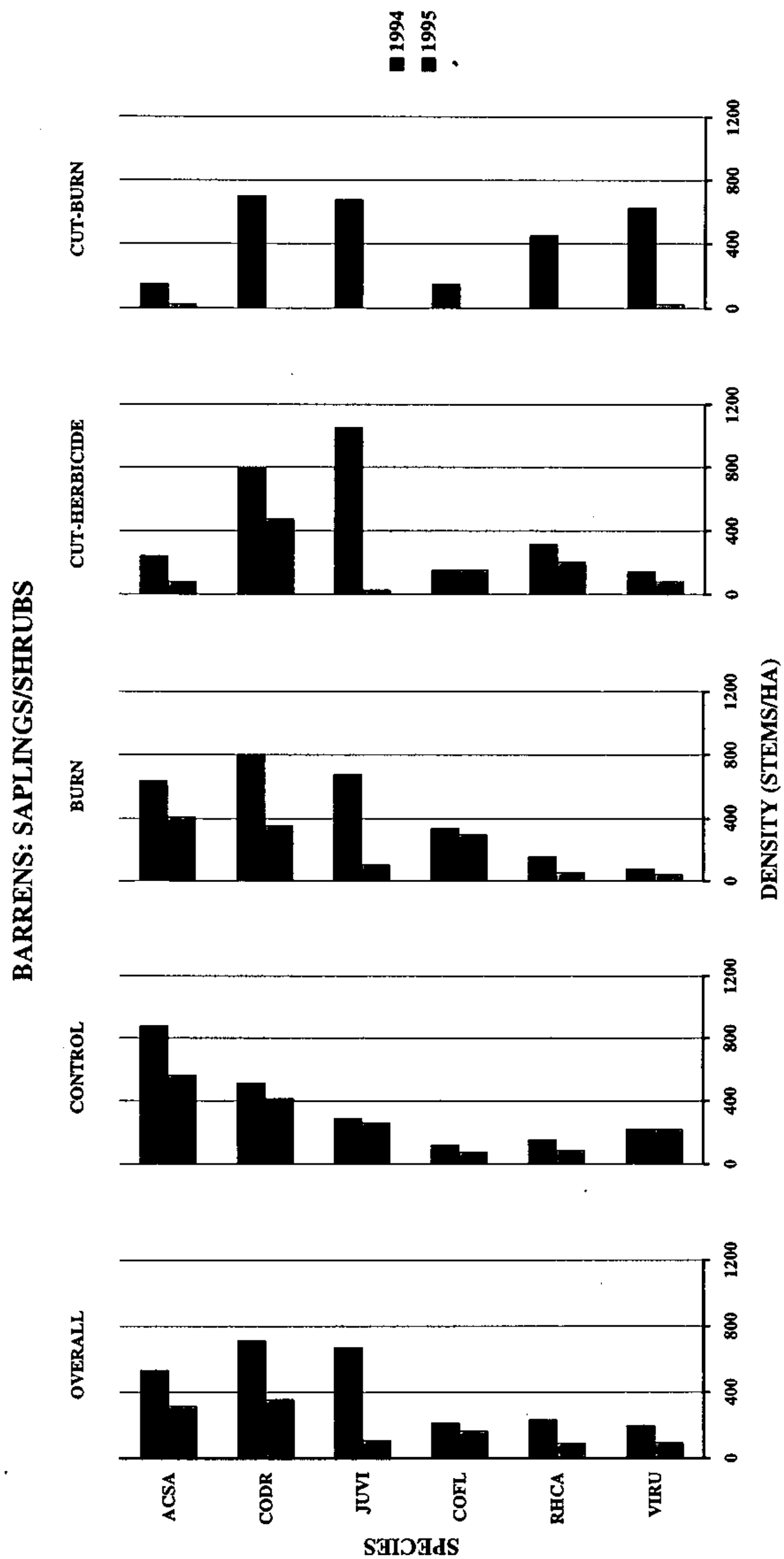
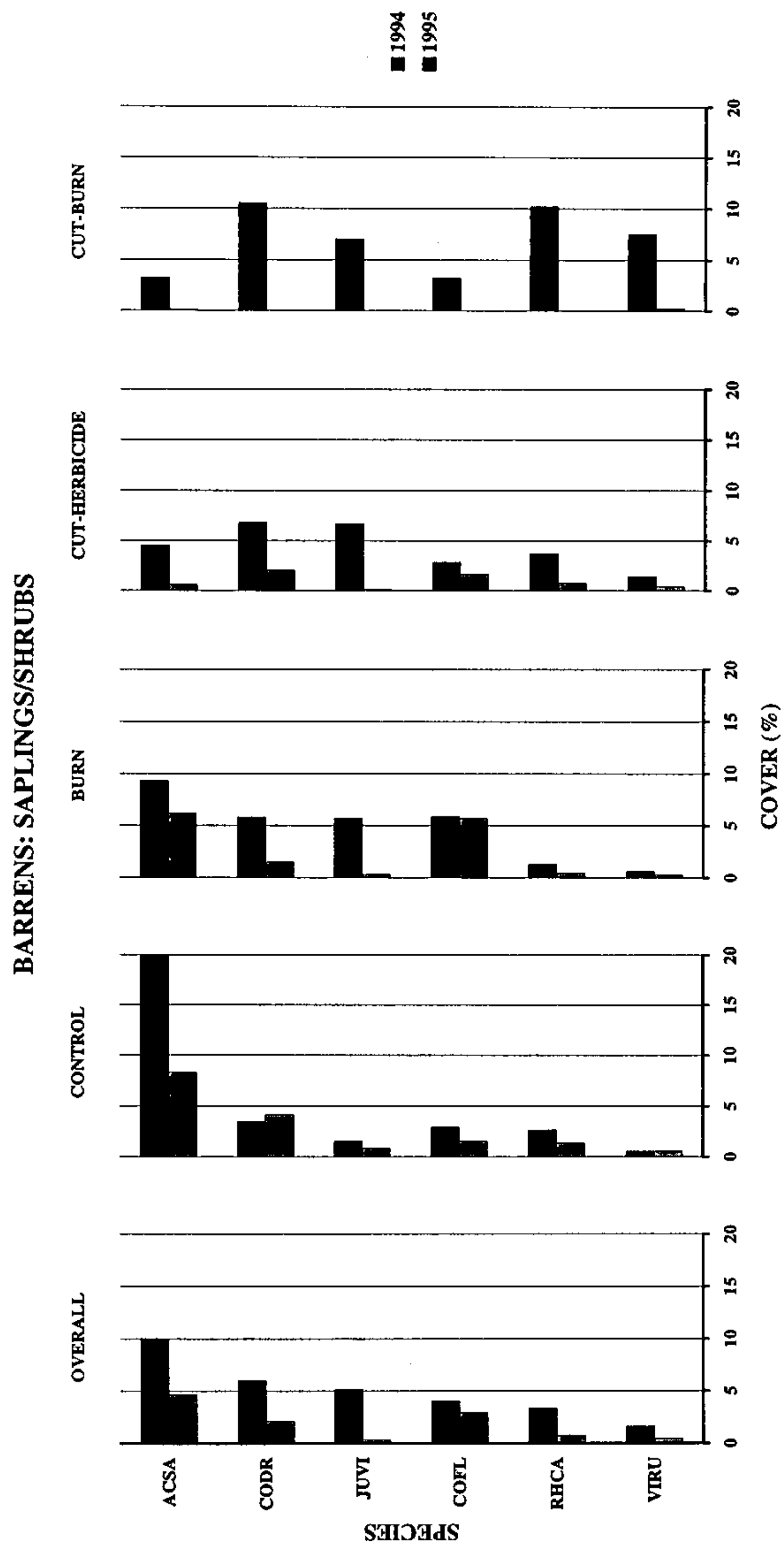

BARRENS: SAPLINGS/SHRUBS
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
1994
1995
ACSA
CODR
JUVI
COFL
RHCA
VIRU
SPECIES
0
400
800
1200
DENSITY (STEMS/HA)

Figure 10. Change in cover for prominent barrens sapling/shrub species. ACSA = *Acer saccharum*, CODR = *Cornus drummondii*, JUVI = *Juniperus virginiana*, COFL = *Cornus florida*, RHCA = *Rhus aromatica*, and VIRU = *Viburnum rufidulum*.


BARRENS: SAPLINGS/SHRUBS
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
1994
1995
ACSA
CODR
JUVI
COFL
RHCA
VIRU
SPECIES
COVER (%)
0
5
10
15
20

species was intentionally cut from four plots originally intended to be part of the cut-burn treatment. While the majority of this reduction was due to cutting, *J. virginiana* was reduced by approximately 50 stems/ha as a result of burning. Within this treatment, all sapling/shrub species either remained the same, decreased or were eliminated in density and cover with treatment (Appendices 11 and 12).

In the cut-herbicide treatment, sapling/shrub density was reduced by 2087 stems/ha (59%) and total cover was reduced by 31.2% (Table 3; Figures 6, 7 and 8). *A. saccharum*, *C. drummondii* and *J. virginiana* were reduced in density by >160 stems/ha and in absolute cover by >3.8% cover, with *J. virginiana* decreasing most, by 1025 stems/ha (98%) and 6.6% cover (a 99% reduction; Figures 9 and 10). Density and cover for 95% of the sapling/shrub species within this treatment remained the same, were reduced or were eliminated with treatment (Appendices 11 and 12).

In the cut-burn treatment, sapling/shrub density was reduced by 3150 stems/ha (91%; Table 3). Of this reduction, only about 100 stems/ha was attributable to burning, however, this amount represented approximately 25% of the stems remaining following cutting. Total cover decreased by 53.1% (a 97% reduction; Table 3; Figure 6). *Cornus drummondii*, *J. virginiana* and *Rhamnus caroliniana*, species prominent before treatment, were eliminated (Figures 9 and 10). *Viburnum rufidulum* was reduced by 600 stems/ha (96%) and 7.3% cover (a 97% reduction). All species were substantially reduced in density and cover or eliminated with treatment, except *Toxicodendron radicans* which showed no change and *Q. rubra* which was present for the first time as stump sprouts which were large enough to be classified as saplings (Appendices 11 and 12). Of the six species present following treatment, *Q. rubra* had the greatest density (125 stems/ha) and *F. americana* had the greatest absolute cover (0.5%).

In the barrens, sapling/shrub density and total cover decreased with both cutting and burning (Table 3; Figure 6). Unlike barrens trees, burning did affect barrens saplings and shrubs, reducing sapling/shrub density by approximately 39% in the burn treatment. Following treatment, *A. saccharum* and *C. drummondii* were still prominent, having densities >300 stems/ha and absolute cover >2.0% (Figures 9 and 10; Appendices 13 and 14). *Cornus florida* also had cover >2.0%. *Juniperus virginiana* was reduced to 109 stems/ha and 0.3% cover.

Barrens: regeneration size class.

Thirty-four woody species, including a number of vines and shrubs, occurred in the barrens within the regeneration size class in 1994 and 1995 (Table 4; Appendices 15 and 16). Prior to treatment, total regeneration density and total cover within the barrens were 68,294 stems/ha and 11.5% cover, respectively (Table 4). The dominant regeneration species within the barrens prior to treatment was *Rhus aromatica*, a small-stemmed shrub, with density of 12,812 stems/ha and 3.5% cover (Figures 11 and 12; Appendices 17 and 18). *Rhus aromatica* accounted for 19% of regeneration density and 30% of regeneration cover in the barrens, and was dominant in all three treatments, however, in the control *A. saccharum* was dominant. Additional species with densities of 7500 stems/ha or more were *A. saccharum* and *Q. prinoides*. Additional species with absolute cover >1.0% were *A. saccharum* and *Toxicodendron radicans*.

Regeneration density and total cover increased within the barrens from 1994 to 1995 with treatment. Density increased by 42,913 stems/ha (63%) and total cover increased by 2.3% (Table 4; Figure 6). Density increased progressively from the burn, to the cut-herbicide, to the cut-burn treatment, with cut-burn regeneration density more than doubling. Total cover increased most in the cut-burn treatment.

In the burn treatment, regeneration density increased by 40,546 stems/ha (58%) in response to burning and windthrow, and the cutting of small *J. virginiana* trees and saplings from one of the upper macroplots (Table 4). *Rhus aromatica* and *T. radicans* increased in density by >5000 stems/ha (>60%), while *P. quinquefolia* and *V. cinerea* increased by >9000 stems/ha (1.9x and 11.3x, respectively; Figure 11). *Acer saccharum* decreased in density by 2084 stems/ha

Figure 11. Change in density for prominent barrens regeneration species. RHAR = *Rhus aromatica*, QUPR = *Quercus prinoides*, ACSA = *Acer saccharum*, TORA = *Toxicodendron radicans*, PAQU = *Parthenocissus quinquefolia*, VICI = *Vitis cinerea*, and VIRU = *Viburnum rufidulum*. Actual stem densities = axis values x 10^3.

BARRENS: REGENERATION

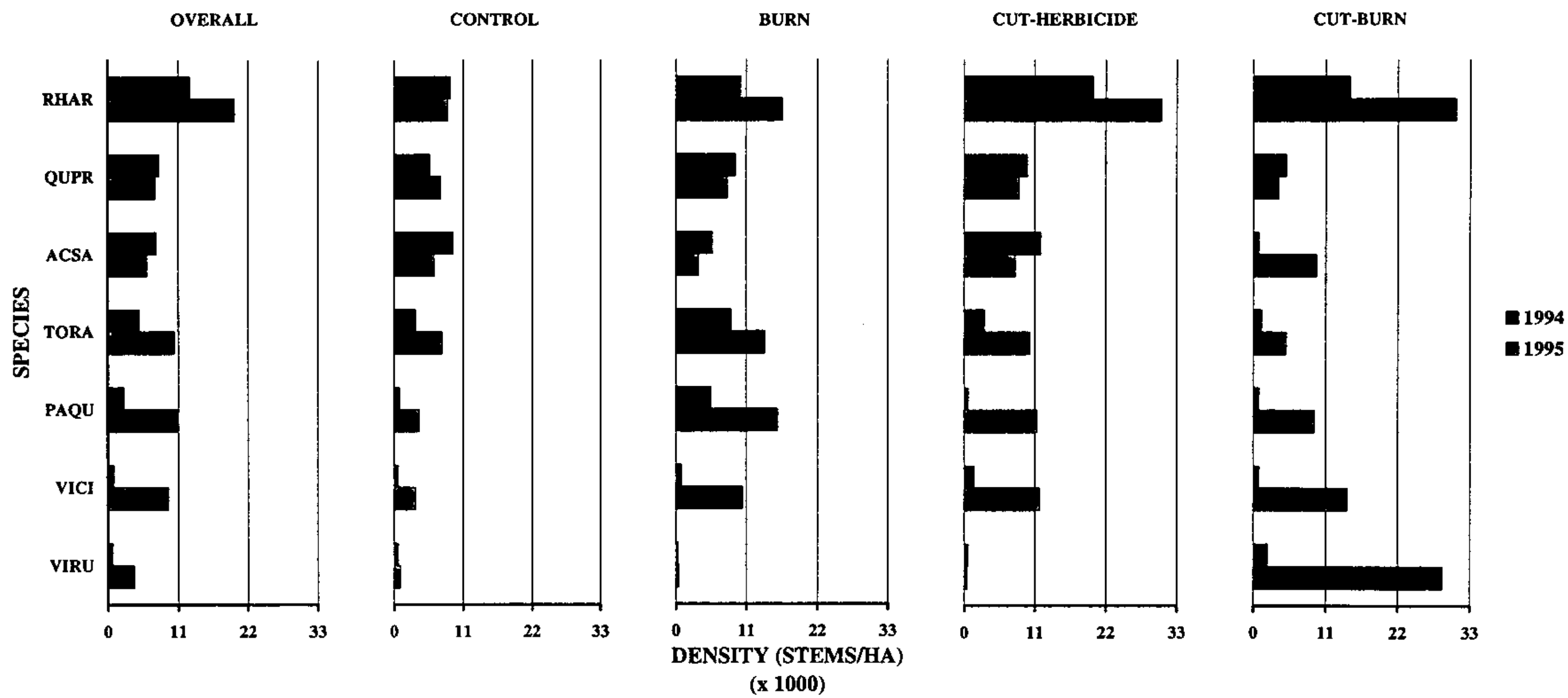
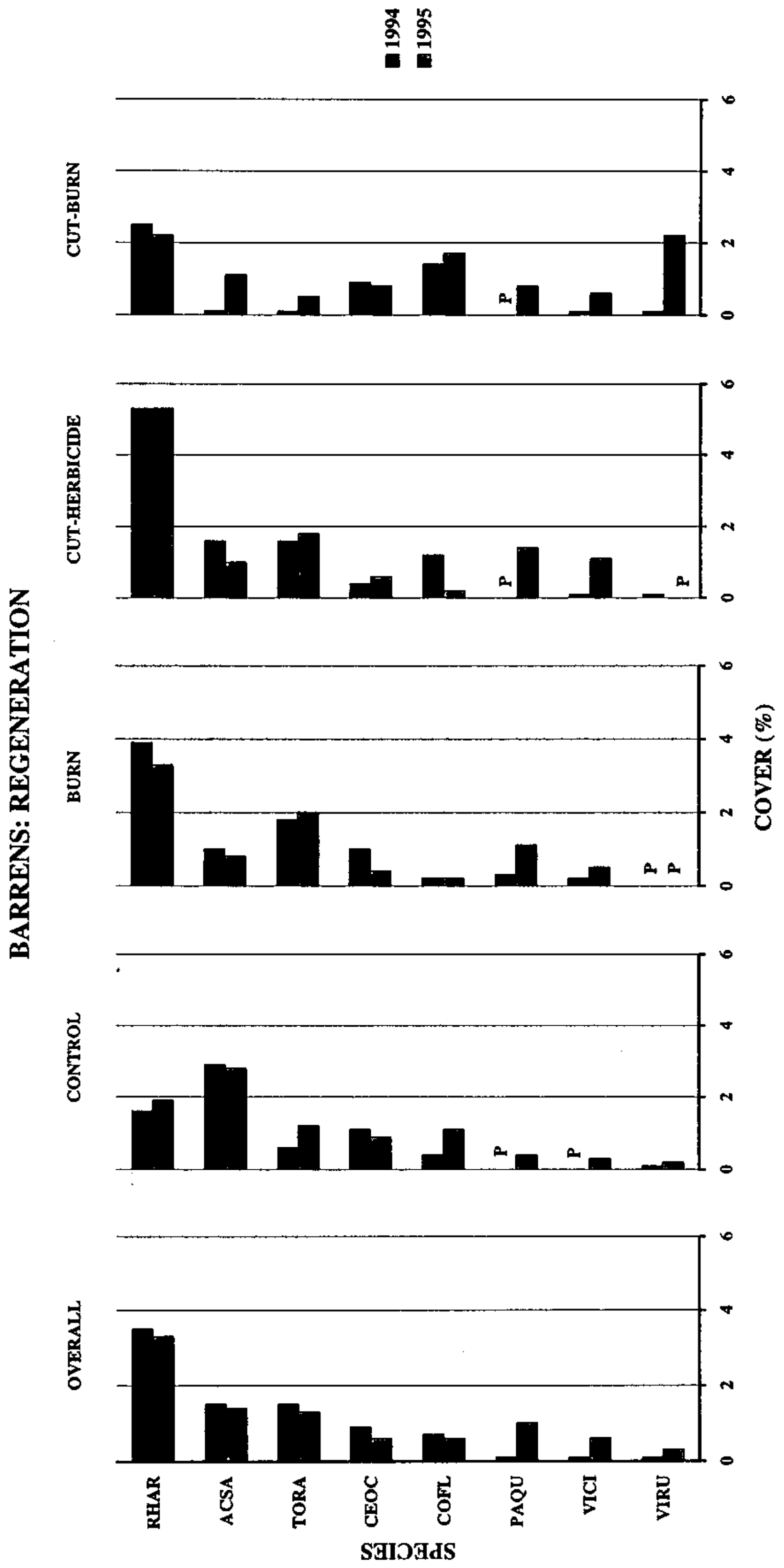


Figure 12. Change in cover for prominent barrens regeneration species. RHAR = *Rhus aromatica*, ACSA = *Acer saccharum*, TORA = *Toxicodendron radicans*, CEOC = *Celtis occidentalis*, COFL = *Cornus florida*, PAQU = *Parthenocissus quinquefolia*, VICI = *Vitis cinerea*, and VIRU = *Viburnum rufidulum*. P = cover present at <0.05%.


BARRENS: REGENERATION
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
1994
1995
RHAR
ACSA
TORA
CEOC
COFL
PAQU
VICI
VIRU
SPECIES
COVER (%)
0
2
4
6
P

(38%). Total cover showed no change (Figure 6). *Parthenocissus quinquefolia* had the largest increase in absolute cover (0.8%), while *R. aromatica* and *Celtis occidentalis* had the largest decreases in cover (0.6% each; Figure 12).

Table 4. Mean density and cover for barrens regeneration and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Total species cover represents the sum of species cover (including overlap). Standard deviations are in italics.

Variable	Year/Change	Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
Density (stems/ha)	1994	68,294 *22,811*	62,093 *25,831*	69,600 *20,832*	75,631 *26,096*	62,098 *18,318*
	1995	111,207 *55,498*	72,307 *32,613*	110,146 *46,131*	124,593 *36,882*	165,430 *99,647*
	Change	+42,913	+10,214	+40,546	+48,962	+103,332
Total species cover (%)	1994	11.5 *7.0*	9.8 *4.2*	12.6 *8.2*	13.9 *8.3*	7.1 *3.2*
	1995	13.8 *7.2*	12.8 *6.9*	12.6 *7.9*	16.7 *7.1*	14.0 *6.3*
	Change	+2.3	+3.0	0.0	+2.8	+6.9
Total number of species (*S*)	1994	34	26	29	24	20
	1995	34	26	32	30	26

In the cut-herbicide treatment, regeneration density increased by 48,962 stems/ha (65%) and total cover increased by 2.8% in response to cutting (Table 4; Figures 6, 7 and 8). *Toxicodendron radicans* increased in density by >7000 stems/ha (2.3x), while *R. aromatica, V. cinerea* and *P. quinquefolia* increased by >10,000 stems/ha (53%, 7x and 17x, respectively; Figure 11). *Acer saccharum* decreased in density by 3957 stems/ha (33%). *Vitis cinerea* and *P. quinquefolia* increased most in absolute cover, by 1.0% or more, while *Cornus florida* had the largest decrease in cover (1.0%; Figure 12).

In the cut-burn treatment, regeneration density increased by 103,332 stems/ha (167%) and total cover nearly doubled, increasing by 6.9%, in response to cutting and burning (Table 4; Figure

6). *Viburnum rufidulum* had the greatest increase in density (26,665 stems/ha) and absolute cover (2.1%), primarily due to sprouting of cut saplings (Figures 11 and 12). *Rhus aromatica* and *V. cinerea* increased by >13,000 stems/ha (1.1x and 16x, respectively), while *Parthenocissus quinquefolia* and *A. saccharum* increased in density by >8000 stems/ha (10x each). *Acer saccharum* increased in absolute cover by 1.0% (10x).

In the barrens, regeneration density and total cover increased with both cutting and burning (Table 4; Figure 6). *Rhus aromatica* remained the dominant species, decreasing slightly in overall cover but increasing substantially (>7000 stems/ha) in overall density (Figures 11 and 12; Appendices 17 and 18). *Acer saccharum* and *Q. prinoides* were two prominent regeneration species in the barrens prior to treatment which decreased in both density and cover with treatment. Three woody vines, *P. quinquefolia*, *T. radicans* and *V. cinerea*, increased substantially in density in all treatments, thus becoming prominent regeneration species in the barrens following treatment.

Glade: tree size class.

Fourteen tree species occurred in the glade in 1994, increasing to 15 species in 1995 (Table 5; Appendices 19, 20 and 21). Included were three species, *Acer saccharum*, *Cornus florida* and *Quercus rubra*, which occurred as canopy cover only. Species occurring as canopy cover only, either within the glade overall or within an individual treatment, indicate species not rooted in the glade or treatment, but with canopy overhanging.

Prior to treatment, basal area, density and total cover within the glade were 9.2 m^2/ha, 912 stems/ha and 39.2% cover, respectively (Table 5). *Juniperus virginiana* was the dominant trees species within the glade, with basal area, density and cover of 7.3 m^2/ha, 675 stems/ha and 31.5% cover, respectively (Figures 13 and 14; Appendices 22, 23 and 24). *Juniperus virginiana* accounted for 70% or more of tree basal area, density and cover in the glade, and was dominant in all three treatments and the control. Additional species with a basal area of 0.4 m^2/ha or more, density of 50 stems/ha or more and cover >1.6% were *Cercis canadensis* and *Fraxinus americana*.

Table 5. Mean basal area, density and cover for glade trees and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Total species cover represents the sum of species cover (including overlap), while total cover excludes species overlap. Standard deviations are in italics.

Variable	Year/Change	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
Basal area (m^2/ha)	1994	9.2	8.9	10.0	7.7	10.3
		5.2	*5.8*	*5.5*	*3.8*	*7.2*
	1995	5.5	8.8	10.0	3.1	0.1
		5.7	*5.8*	*5.5*	*3.4*	*0.2*
	Change	-3.7	-0.1	0.0	-4.6	-10.2
Density (stems/ha)	1994	912	850	1125	925	750
		350	*451*	*222*	*435*	*265*
	1995	562	825	1125	275	25
		514	*457*	*222*	*222*	*50*
	Change	-350	-25	0	-650	-725
Total cover (%)	1994	39.2	43.5	39.8	30.0	43.5
		12.5	*14.5*	*10.8*	*11.0*	*13.0*
	1995	24.4	42.8	39.5	6.6	8.9
		20.0	*12.3*	*12.3*	*6.7*	*12.2*
	Change	-14.8	-0.7	-0.3	-23.4	-34.6
Total species cover (%)	1994	43.5	48.6	44.1	34.3	46.9
		13.7	*16.5*	*7.6*	*17.0*	*12.3*
	1995	27.7	48.9	45.8	6.9	9.4
		22.6	*13.1*	*11.6*	*6.5*	*12.5*
	Change	-15.8	+0.3	+1.7	-27.4	-37.5
Total number of species (*S*)	1994	14	8	10	7	7
	1995	15	8	11	8	5

Figure 13. Change in basal area for prominent glade tree species. JUVI = *Juniperus virginiana*, QUPR = *Quercus prinoides*, FRAM = *Fraxinus americana*, CECA = *Cercis canadensis*, and QUST = *Quercus stellata*.

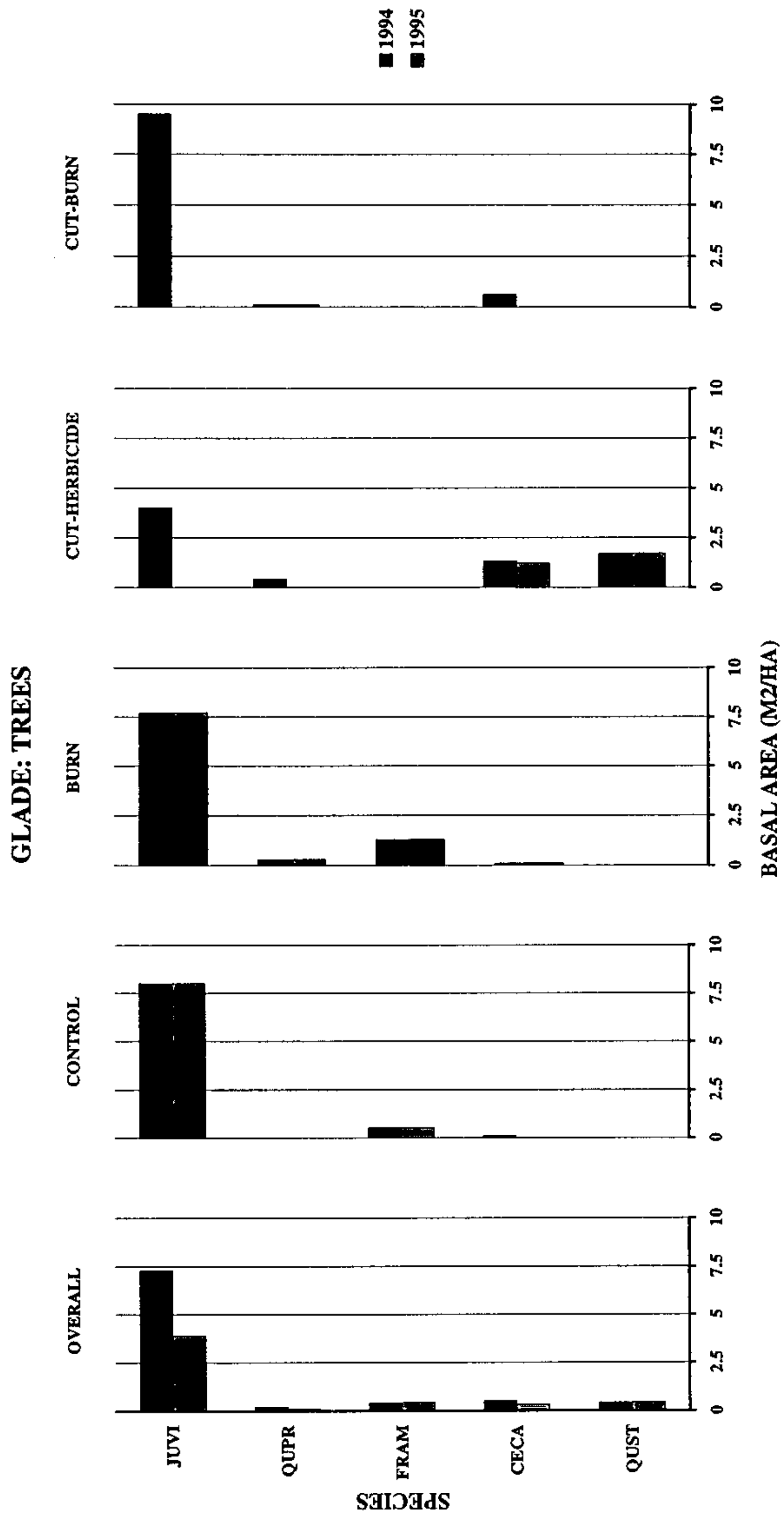
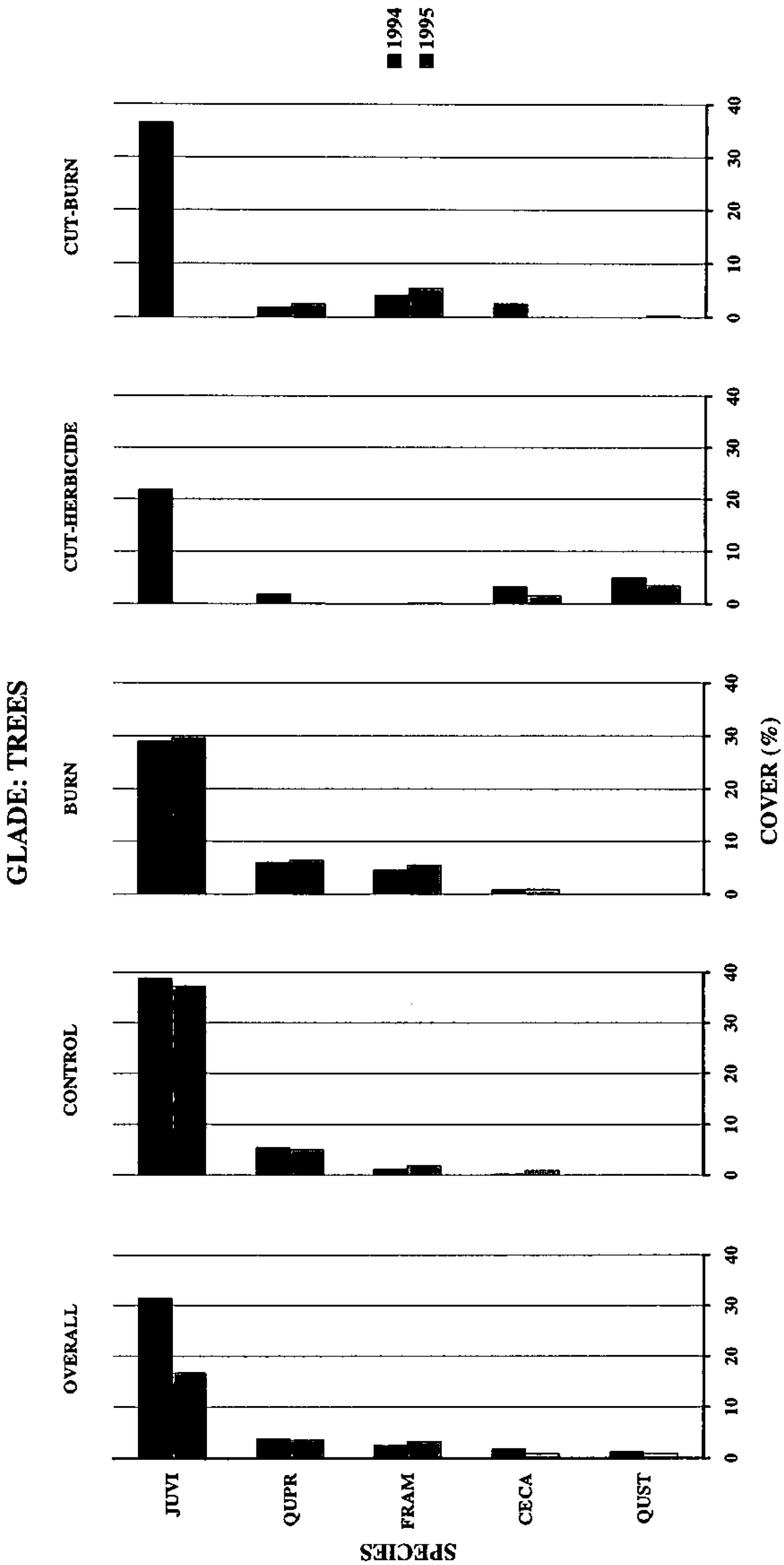

GLADE: TREES
1994
1995
CUT-BURN
CUT-HERBICIDE
BURN
CONTROL
OVERALL
0
2.5
5
7.5
10
BASAL AREA (M2/HA)
JUVI
QUPR
FRAM
CECA
QUST
SPECIES

Figure 14. Change in cover for prominent glade tree species. JUVI = *Juniperus virginiana*, QUPR = *Quercus prinoides*, FRAM = *Fraxinus americana*, CECA = *Cercis canadensis*, and QUST = *Quercus stellata*.


GLADE: TREES
1994
1995
CUT-BURN
CUT-HERBICIDE
BURN
CONTROL
OVERALL
0
10
20
30
40
COVER (%)
JUVI
QUPR
FRAM
CECA
QUST
SPECIES

Quercus stellata had basal area of 0.4 m^2/ha and *Quercus prinoides* had absolute cover of 3.8%. As much as half of the *F. americana* and *Q. prinoides* cover may have been attributable to stems rooted outside the glade.

Basal area, density and total cover of trees decreased within the glade from 1994 to 1995 with treatment. Basal area was reduced by 3.7 m^2/ha (40%), density by 350 stems/ha (38%) and total cover by 14.8% (Table 5; Figure 15). The majority of decrease was attributable to the two cut treatments. Differences noted between decreases in total and individual species cover within treatments are indicative of species canopy overlap (Table 5).

In the cut-herbicide treatment, basal area was reduced by 4.6 m^2/ha (60%) and total cover was reduced by 23.4% (Table 5; Figure 15). *Juniperus virginiana*, with basal area of 4.0 m^2/ha and 21.8% cover prior to treatment, was eliminated except as cover (0.1%), as was *Q. prinoides* (Figures 13 and 14).

Burning did not affect trees in the cut-burn treatment, whereas cutting reduced basal area by 10.2 m^2/ha (99%) and total cover by 34.6% (Table 5; Figures 15, 16 and 17. *Juniperus virginiana*, which had basal area of 9.5 m^2/ha and 36.5% cover prior to treatment, was eliminated, as was *Cercis canadensis* (Figures 13 and 14). *Quercus prinoides*, the only remaining species rooted in the treatment, showed no change in basal area. Four additional species were present as cover only (Appendix 21).

In the glade (as in the barrens), tree basal area, density and total cover were substantially reduced with cutting, but were unaffected by burning (Table 5; Figure 15). Following treatment, the burn treatment differed markedly from the two cut treatments in that burn treatment basal area, density and cover changed little or not at all, with *Juniperus virginiana* remaining dominant, while cut-herbicide and cut-burn treatment basal area, density and cover decreased substantially, resulting in the near to total elimination of *J. virginiana* (Figures 13 and 14; Appendices 22, 23 and 24).

Figure 15. Change in total cover of glade vegetation.

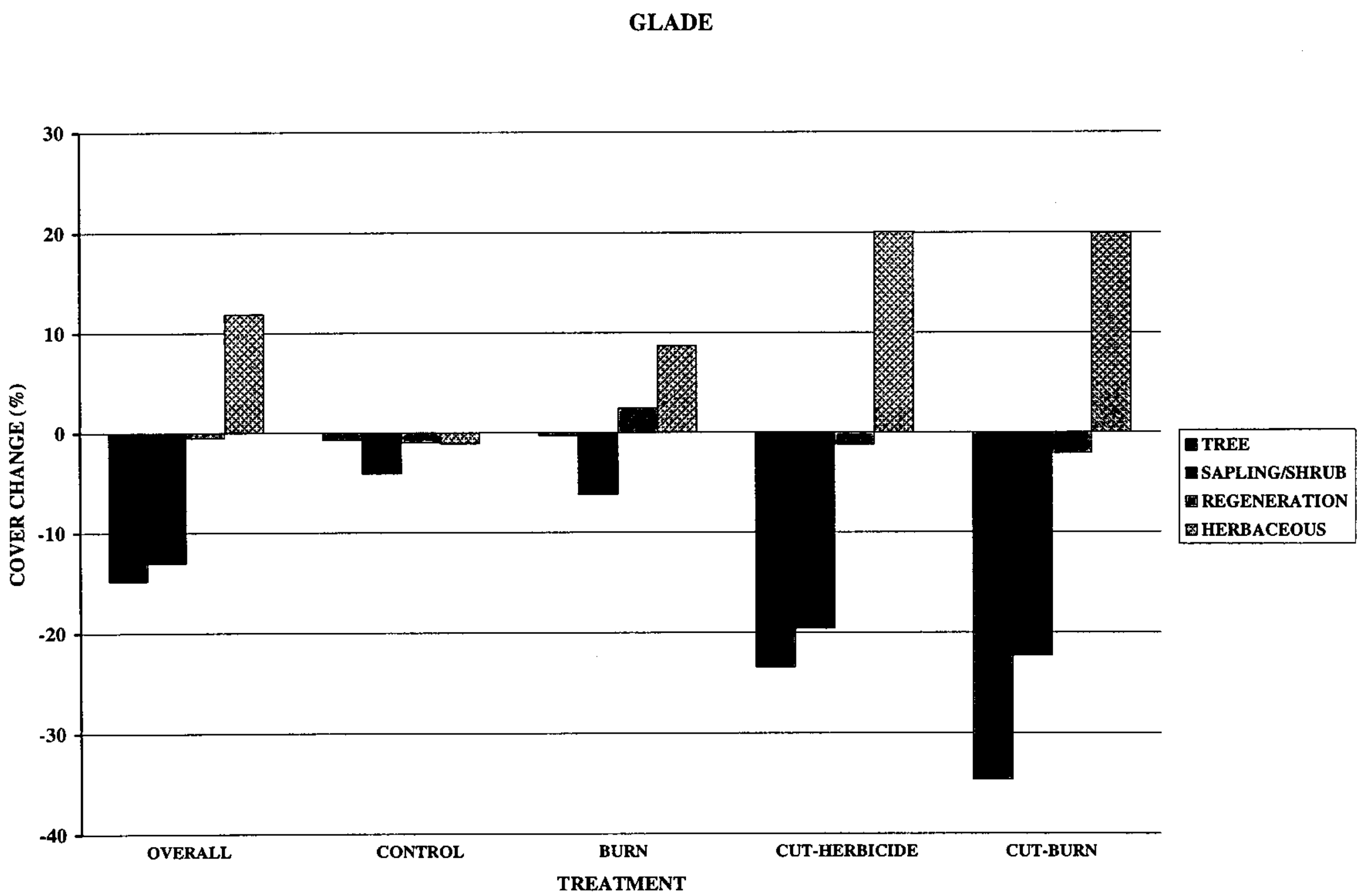
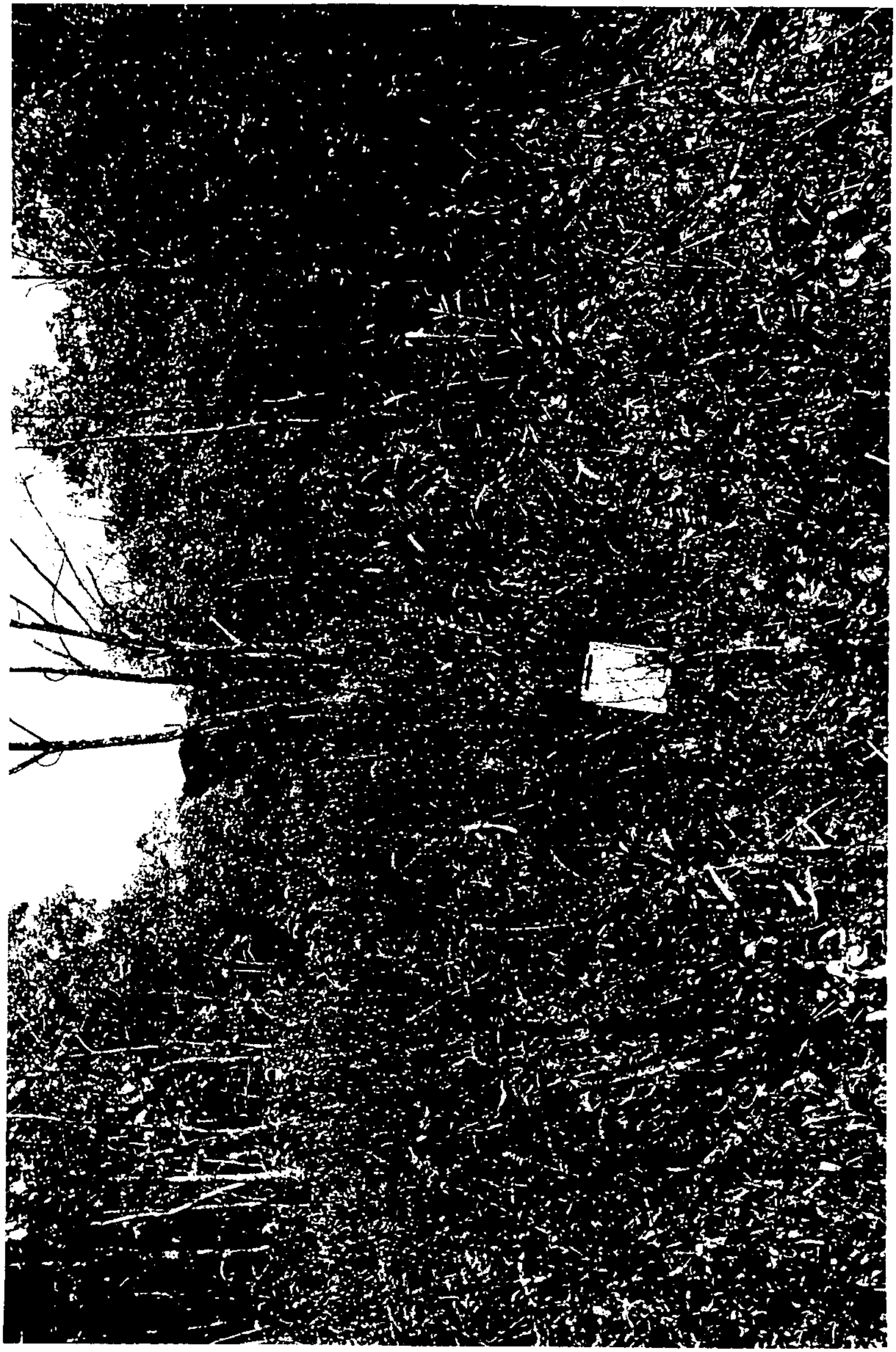

GLADE
30
20
10
0
-10
-20
-30
-40
COVER CHANGE (%)
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
TREATMENT
TREE
SAPLING/SHRUB
REGENERATION
HERBACEOUS

Figure 16. Upper glade cut-burn plot 1 prior to treatment (October 1994).

Figure 17. Upper glade cut-burn plot 1 following treatment (October 2, 1995).



Glade: sapling and shrub size class.

Twenty-one sapling/shrub species occurred in the glade in 1994 and 1995 (Table 6; Appendices 25 and 26). Prior to treatment, total sapling/shrub density and total cover within the glade were 3456 stems/ha and 26.4% cover, respectively (Table 6). *Juniperus virginiana* was the dominant sapling/shrub species, with density and total cover of 1469 stems/ha and 11.1% cover, respectively (Figures 18 and 19; Appendices 27 and 28). *Juniperus virginiana* accounted for 42% of sapling/shrub density and cover, and was dominant throughout the glade with the exception of cover in the cut-herbicide treatment, which *Quercus prinoides* dominated. Additional species with densities of 475 stems/ha or more and absolute cover >2.4% were *Cornus drummondii* and *Rhus copallina*.

Table 6. Mean density and cover for glade saplings/shrubs and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Total species cover represents the sum of species cover (including overlap). Standard deviations are in italics.

Variable	Year/Change	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
Density (stems/ha)	1994	3456 *1484*	5175 *936*	3700 *606*	2525 *1159*	2425 *1352*
	1995	2163 *2145*	5000 *1804*	2625 *842*	900 *577*	125 *150*
	Change	-1293	-175	-1075	-1625	-2300
Total species cover (%)	1994	26.4 *11.0*	37.3 *2.3*	20.6 *6.9*	24.6 *9.8*	23.3 *15.4*
	1995	13.4 *13.3*	33.2 *4.7*	14.4 *4.9*	5.0 *3.5*	1.0 *1.4*
	Change	-13.0	-4.1	-6.2	-19.6	-22.3
Total number of species (*S*)	1994	21	17	15	8	13
	1995	21	19	14	7	2

Saplings/shrub density and total cover decreased within the glade from 1994 to 1995. Density was reduced by 1293 stems/ha (37%) and total cover was reduced by 13.0% (Table 6;

Figure 18. Change in density for prominent glade sapling/shrub species. JUVI = *Juniperus virginiana*, RHCO = *Rhus copallina*, CODR = *Cornus drummondii*, QUPR = *Quercus prinoides*, and RHAR = *Rhus aromatica*.

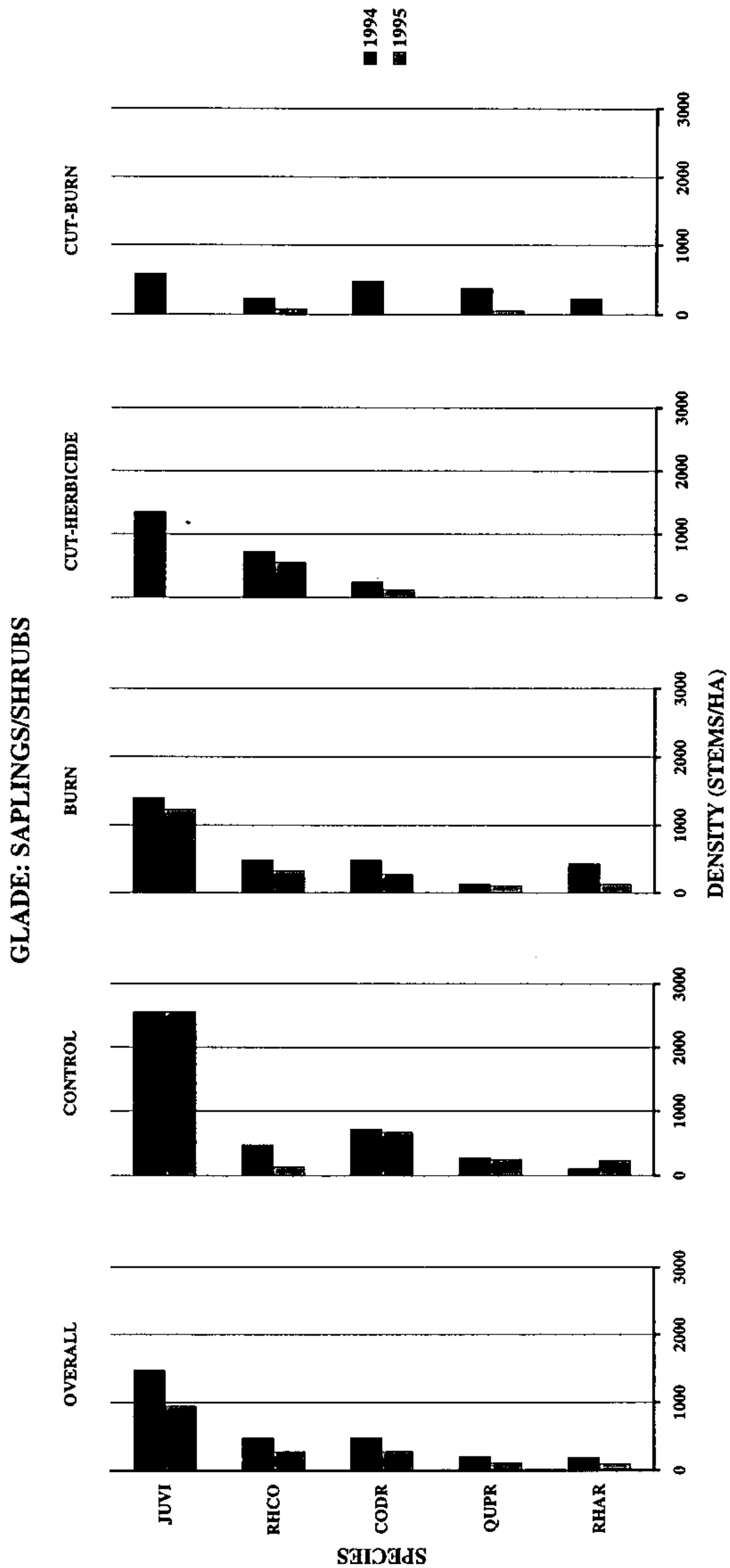
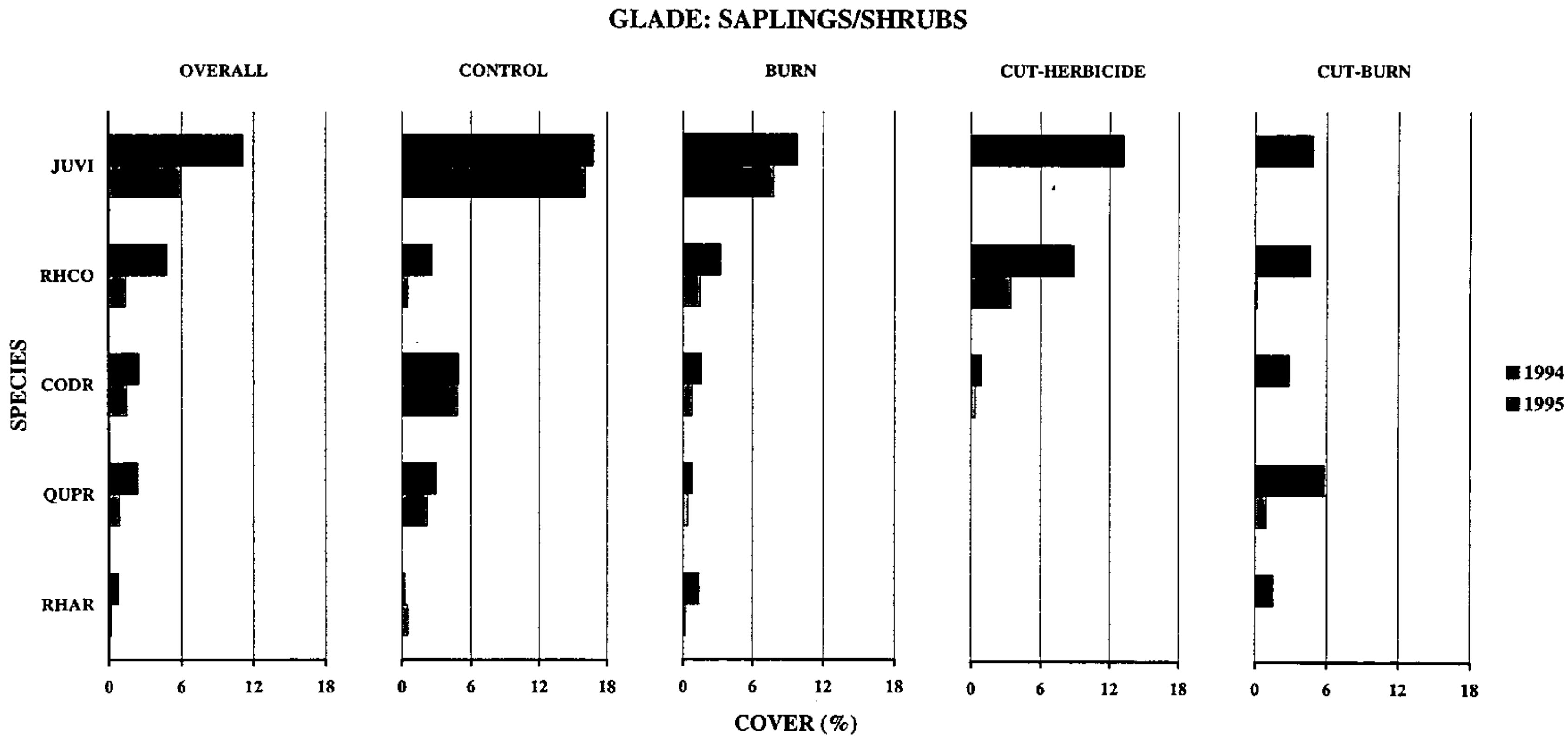

GLADE: SAPLINGS/SHRUBS
1994
1995
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
JUVI
RHCO
CODR
QUPR
RHAR
SPECIES
0
1000
2000
3000
DENSITY (STEMS/HA)

Figure 19. Change in cover for prominent glade sapling/shrub species. JUVI = *Juniperus virginiana*, RHCO = *Rhus copallina*, CODR = *Cornus drummondii*, QUPR = *Quercus prinoides*, and RHAR = *Rhus aromatica*.



GLADE: SAPLINGS/SHRUBS
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
SPECIES
JUVI
RHCO
CODR
QUPR
RHAR
0
6
12
18
COVER (%)
1994
1995

Figure 15). The burn, cut-herbicide and cut-burn treatments showed progressively larger decreases in density and cover with treatment.

The burn treatment reduced sapling/shrub density by 1075 stems/ha (29%) and total cover by 6.2% (Table 6; Figure 15). *Cornus drummondii*, *J. virginiana*, *Rhus aromatica*, and *Rhus copallina* decreased in density by 150 stems/ha or more and in absolute cover by 0.8% or more, with *R. aromatica* having the greatest decrease in density (300 stems/ha or 71%) and *J. virginiana* having the greatest decrease in absolute cover (2.0%; Figures 18 and 19). Density and cover for 80% of sapling/shrub species in this treatment either remained the same, were reduced or were eliminated with treatment (Appendices 25 and 26).

The cut-herbicide treatment reduced sapling/shrub density by 1625 stems/ha (a 64% reduction) and total cover by 19.6% (Table 6, Figure 15). *Juniperus virginiana*, which had 1350 stems/ha and 13.2% cover prior to treatment, was eliminated (Figures 18 and 19). *Rhus copallina* was reduced in density by 175 stems/ha (24%) and in absolute cover by 5.5% (a 62% reduction). All species either remained the same, were reduced or were eliminated in density and cover following treatment, except *Cercis canadensis* which was present for the first time as stump sprouts which were large enough to be classified as saplings (Appendices 25 and 26).

The cut-burn treatment reduced sapling/shrub density by 2300 stems/ha (95%) and total cover by 22.3%, due primarily to cutting (Table 6; Figures 15, 16 and 17). Shrub-sized stems of *R. aromatica* were eliminated with burning (Figures 18 and 19). *Juniperus virginiana*, which had 575 stems/ha and 4.8% cover prior to treatment, was eliminated along with 12 other sapling/shrub species (Figures 18 and 19; Appendices 25 and 26). Only two species, *Q. prinoides* and *R. copallina*, remained. *Quercus prinoides* was reduced in density by 325 stems/ha (87%) and in absolute cover by 4.9%. *Rhus copallina* was reduced in density by 150 stems/ha (67%) and retained negligible cover (0.1%).

In the glade (as in the barrens), sapling/shrub density and total cover decreased with both cutting and burning (Table 6; Figure 15). *Juniperus virginiana* was eliminated by cutting, but little reduced by a single burn, shrub-sized stems of *R. aromatica* were substantially reduced by fire, and both cutting and burning proved to be effective means of reducing *Cornus drummondii* and *R. copallina* in this size class (Figures 18 and 19; Appendices 27 and 28). Unlike glade trees, burning did affect glade saplings and shrubs, reducing sapling/shrub density by approximately 30% in the burn treatment. *Juniperus virginiana* remained the dominant sapling/shrub species, even though eliminated from the two cut treatments, with a density of 944 stems/ha and absolute cover of 5.9%.

Glade: regeneration size class.

Twenty-five woody species occurred in the glade within the regeneration size class in 1994 (Table 7; Appendices 29 and 30). This was reduced to 24 species in 1995. Prior to treatment, total regeneration density and total cover within the glade were 48,650 stems/ha and 12.2% cover, respectively (Table 7). The dominant regeneration species within the glade (as in the barrens) was *Rhus aromatica*, a small-stemmed shrub, with density of 24,375 stems/ha and 8.2% cover (Figures 20 and 21; Appendices 31 and 32). *Rhus aromatica* accounted for 50% of regeneration density and 67% of regeneration cover, and was dominant throughout the glade with the exception of density in the cut-herbicide treatment, which *Quercus prinoides* dominated. The next most abundant species was *Quercus prinoides* with a density of 7812 stems/ha and absolute cover of 1.2%.

Regeneration density increased while total cover decreased within the glade from 1994 to 1995 with treatment. Regeneration density increased by 37,190 stems/ha (76%), while total cover decreased by 0.5% (Table 7; Figure 15). Regeneration density increased least in the cut-herbicide treatment, followed by the burn treatment and the cut-burn treatment, where density more than doubled. Total cover decreased in the cut-herbicide and cut-burn treatments, and increased in the burn treatment.

Figure 20. Change in density for prominent glade regeneration species. RHAR = *Rhus aromatica*, QUPR = *Quercus prinoides*, RHCO = *Rhus copallina*, CECA = *Cercis canadensis*, CEOC = *Celtis occidentalis*, and CODR = *Cornus drummondii*. Actual stem densities = axis values x 10^3. The cut-burn axis is scaled differently than the other four axes to accommodate the large number of *R. aromatica* stems in this treatment.

GLADE: REGENERATION

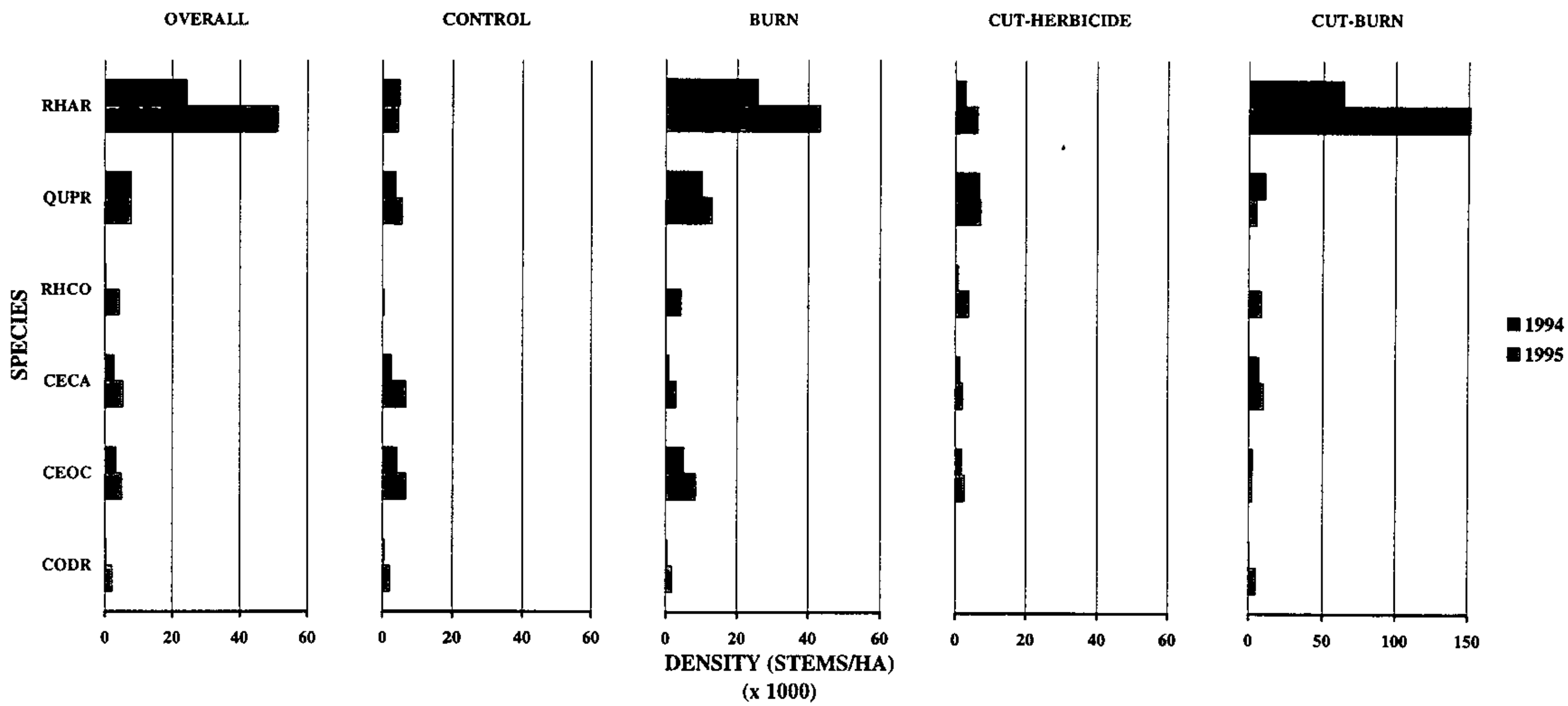


Figure 21. Change in cover for prominent glade regeneration species. RHAR = *Rhus aromatica*, QUPR = *Quercus prinoides*, RHCO = *Rhus copallina*, and CECA = *Cercis canadensis*. P = cover present at <0.05%.

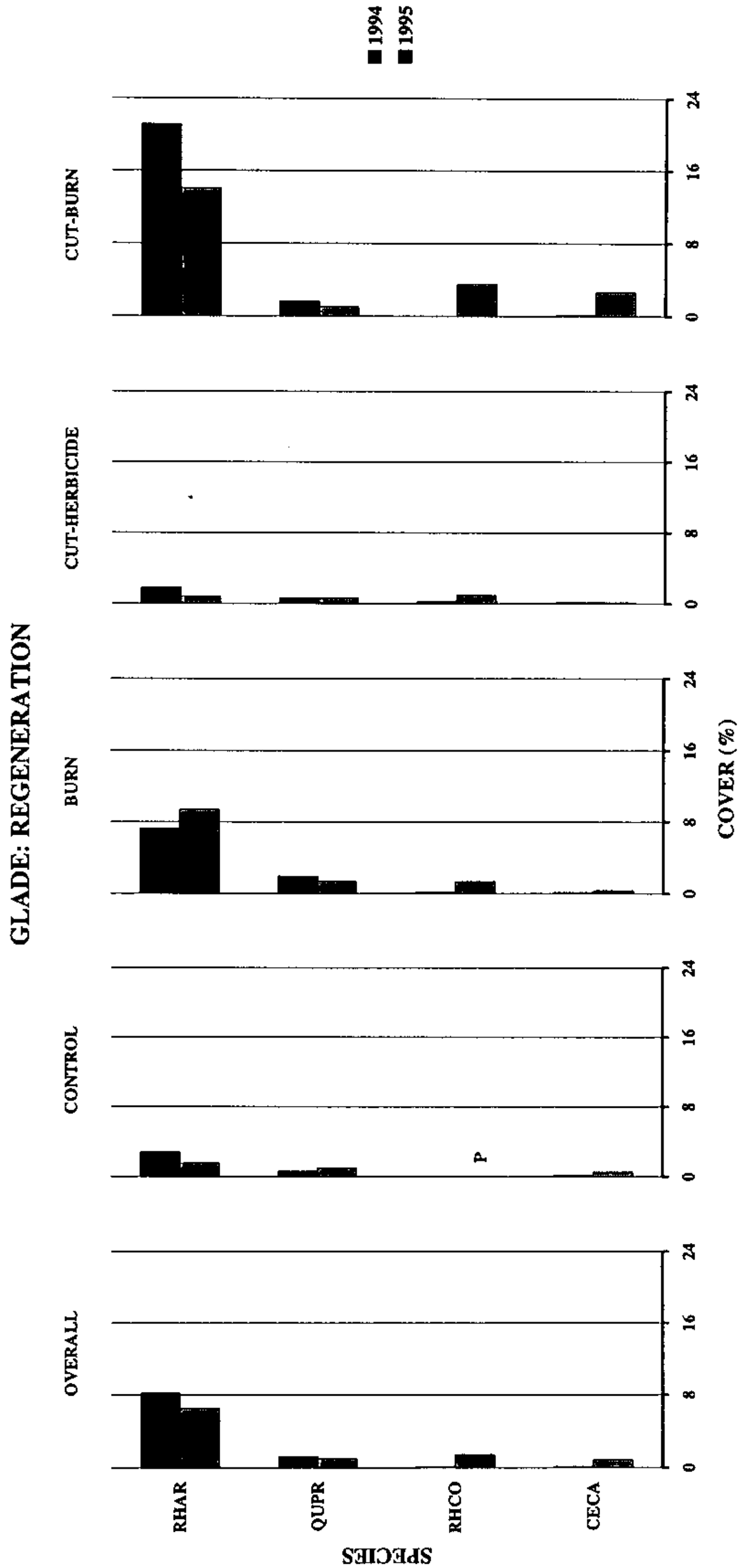

GLADE: REGENERATION
1994
1995
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
P
0
8
16
24
COVER (%)
RHAR
QUPR
RHCO
CECA
SPECIES

Table 7. Mean density and cover for glade regeneration and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Total species cover represents the sum of species cover (including overlap). Standard deviations are in italics.

Variable	Year/Change	Overall n=16	CN n=4	BO n=4	CH n=4	CB n=4
Density (stems/ha)	1994	48,650	33,755	51,670	17,510	91,675
		43,488	*22,322*	*28,827*	*12,811*	*62,399*
	1995	85,840	45,430	87,088	25,838	185,000
		89,709	*29,354*	*38,387*	*32,471*	*129,453*
	Change	+37,190	+11,675	+35,418	+8328	+93,325
Total species cover (%)	1994	12.2	7.6	12.5	4.1	24.7
		11.4	*8.4*	*12.0*	*3.1*	*10.3*
	1995	11.7	6.6	14.9	2.9	22.6
		11.7	*5.0*	*12.5*	*3.9*	*13.3*
	Change	-0.5	-1.0	+2.4	-1.2	-2.1
Total number of species (S)	1994	25	19	15	13	17
	1995	24	19	21	12	13

In the burn treatment, regeneration density increased by 35,418 stems/ha (69%) and total cover increased by 2.4%, in response to burning (Table 7; Figure 15). *Rhus aromatica* had the greatest increase in density (17,500 stems/ha or 68%) and in absolute cover (2.2%; Figures 20 and 21). *Rhus copallina* increased in density by 4165 stems/ha from zero stems/ha prior to treatment and in absolute cover by 1.2%. *Celtis occidentalis* and *Q. prinoides* increased in density by >2900 stems/ha.

In the cut-herbicide treatment, regeneration density increased by 8328 stems/ha (48%) and total cover decreased by 1.2%, in response to cutting (Table 7; Figure 15). *Rhus aromatica* and *R. copallina* increased in density by >2900 stems/ha (114% and 3.5x, respectively; Figure 20). *Rhus aromatica* decreased in absolute cover by 1.0% (Figure 21).

In the cut-burn treatment, regeneration density increased by 93,325 stems/ha (102%) and total cover decreased by 2.1%, in response to cutting and burning (Table 7; Figures 15, 16 and 17). *Rhus aromatica* had the greatest increase in density (87,080 stems/ha or 137%) and the greatest decrease in absolute cover (7.1%; Figures 20 and 21). *Cercis canadensis*, *Cornus drummondii* and *Rhus copallina* increased in density by >2900 stems/ha, with *Rhus copallina* increasing most, by 8332 stems/ha from zero stems/ha prior to treatment. *Quercus prinoides* decreased in density by 5832 stems/ha (54%). *Cercis candensis* and *Rhus copallina* increased in absolute cover by 2.5% or more.

In the glade, following treatment, *R. aromatica* remained the dominant regeneration species, increasing in density while decreasing in absolute cover, as in the barrens (Figures 20 and 21; Appendices 31 and 32). *Rhus aromatica* increased most substantially in the two burn treatments, where it was most abundant prior to treatment and where reduction or elimination of shrub sized stems occurred (*R. aromatica* was not present as a shrub in the cut-herbicide treatment). Following treatment, *R. aromatica* accounted for 60% of regeneration density and 56% of regeneration cover. *Rhus copallina* also increased substantially in density (3958 stems/ha or 19x), particularly in treatments involving burning.

Herbaceous Vegetation

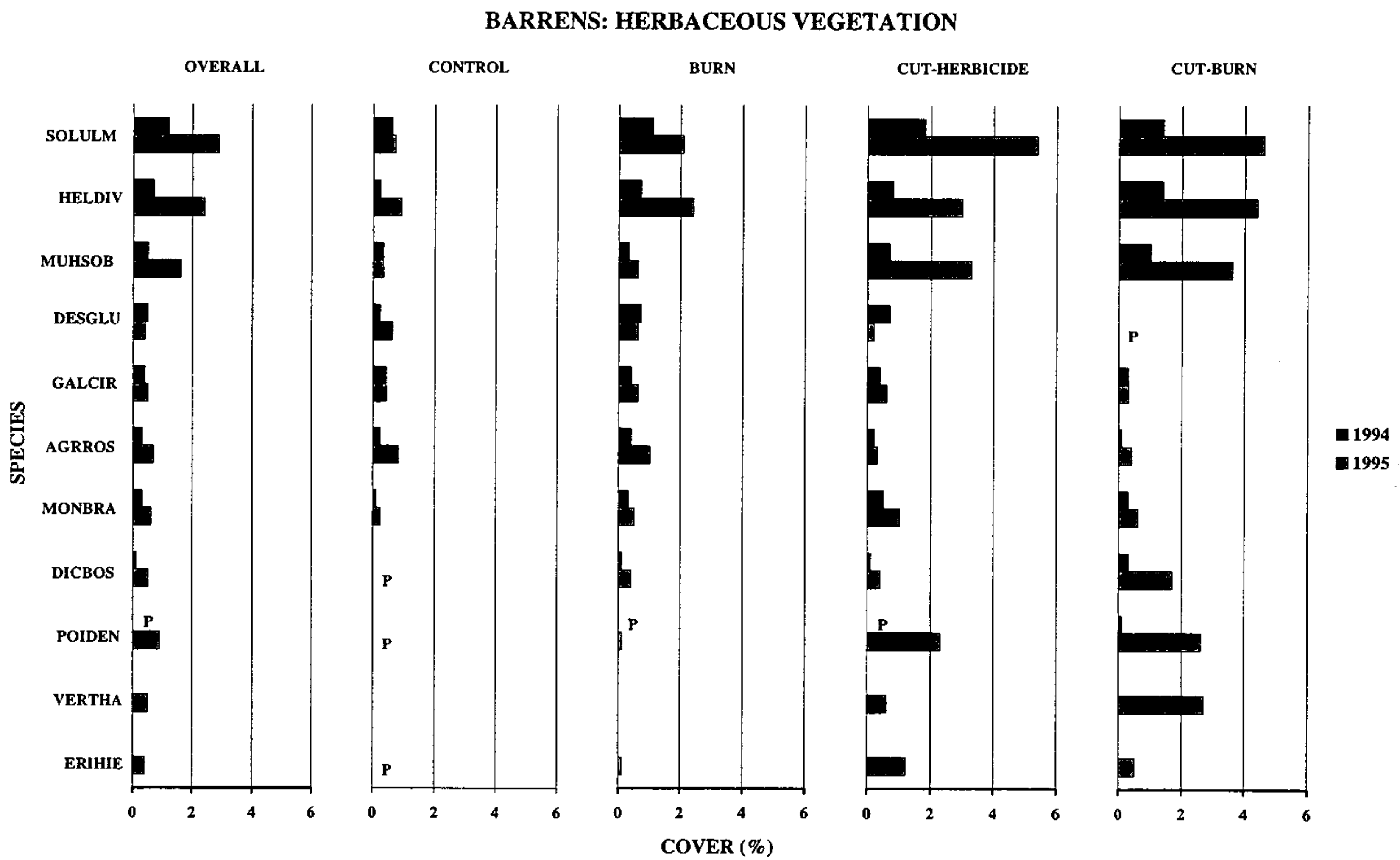
Barrens.

Sixty-six herbaceous species occurred within the barrens in 1994, increasing to 94 species in 1995, of which 31 species were new (Table 8; Appendix 33). Prior to treatment, total cover of herbaceous vegetation within the barrens was 6.4% (Table 8). *Solidago ulmifolia* was the most abundant herbaceous species within the barrens, with average cover of 1.2%, followed by *Helianthus divaricatus* (0.7%), *Desmodium glutinosum* and *Muhlenbergia sobolifera* (0.5% each), and *Galium circaezans* (0.4%; Figure 22; Appendix 34).

Total cover of herbaceous vegetation increased within the barrens from 1994 to 1995 by 10.9% to 2.7x the pretreatment amount (Table 8; Figure 6). Total herbaceous cover increased progressively in the burn, cut-herbicide and cut-burn treatments.

Burning nearly doubled total herbaceous cover (+5.9%; Table 8; Figure 6). *Helianthus*

Figure 22. Change in cover for prominent barrens herbaceous species. SOLULM = *Solidago ulmifolia*, HELDIV = *Helianthus divaricatus*, MUHSOB = *Muhlenbergia sobolifera*, DESGLU = *Desmodium glutinosum*, GALCIR = *Galium circaezans*, AGRROS = *Agrimonia rostellata*, MONBRA = *Monarda bradburiana*, DICBOS = *Dichanthelium boscii*, POIDEN = *Poinsettia dentata*, VERTHA = *Verbascum thapsis*, and EREHIE = *Erechtites hieracifolia*. P = cover present at <0.05%.


BARRENS: HERBACEOUS VEGETATION
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
SOLULM
HELDIV
MUHSOB
DESGLU
GALCIR
AGRROS
MONBRA
DICBOS
POIDEN
VERTHA
ERIHIE
SPECIES
P
0
2
4
6
COVER (%)
1994
1995

divaricatus replaced *S. ulmifolia* as the most abundant herbaceous species, increasing by 1.7%, followed by *S. ulmifolia* (+1.0%) and *Agrimonia rostellata* (+0.6%; Figure 22).

Table 8. Mean cover and diversity indices for barrens herbaceous vegetation and change in cover with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Total species cover represents the sum of species cover (including overlap). Standard deviations are in italics.

Variable	Year/Change	Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
Total species cover (%)	1994	6.4	3.8	7.2	8.0	6.3
		4.3	*3.3*	*4.7*	*4.2*	*4.0*
	1995	17.3	6.3	13.1	27.6	31.0
		14.2	*5.2*	*9.6*	*11.1*	*21.6*
	Change	+10.9	+2.5	+5.9	+19.6	+24.7
Total number of species (*S*)	1994	66	37	53	48	25
	1995	94	43	60	74	52
Mean species richness (*S*/*n*)	1994	16.2	12.4	17.3	18.9	15.0
	1995	21.3	13.9	20.8	27.8	25.0
Shannon's index (*H*')	1994	3.16	3.03	3.13	2.95	2.42
	1995	3.30	2.94	3.09	3.14	2.88
Evenness (*E*)	1994	0.75	0.84	0.79	0.76	0.75
	1995	0.73	0.78	0.75	0.73	0.73

Cutting more than tripled total herbaceous cover (+19.6%) and increased herbaceous species richness (*S*/*n*) by 47% (Table 8; Figures 6, 7 and 8). *Solidago ulmifolia* remained the most abundant herbaceous species, increasing by 3.6%, followed by *Muhlenbergia sobolifera* (+2.6%), *H. divaricatus* (+2.2%), *Poinsettia dentata* (+2.3%) from negligible (0.01%) cover, and *Erechtites hieracifolia* (+1.2%) from zero cover (Figure 22). *Desmodium glutinosum* decreased by 0.5%.

Cutting and burning increased total herbaceous cover (+24.7%), to nearly 5x the pretreatment amount, herbaceous species richness (*S*/*n*; +67%) and diversity (*H*'; +0.46; Table 8; Figure 6). *Solidago ulmifolia* remained the most abundant herbaceous species, increasing by 3.2%, followed by *H. divaricatus* (+3.0%), *Muhlenbergia sobolifera* (+2.6%), *Verbascum thapsus*

(+2.7%) from zero cover, *P. dentata* (+2.5%) from minimal (0.1%) cover, *Dichanthelium boscii* (+1.4%), *Acalypha gracilens* (+1.6) from minimal (0.1%) cover, *S. petiolaris* (+1.2%), and *Glandularia canadensis* (+1.5%) from zero cover (Figure 22; Appendix 34).

In the barrens, herbaceous species richness (*S/n*) increased 31% while total herbaceous cover increased 1.7x with cutting and burning (Table 8). *Solidago ulmifolia* and *Helianthus divaricatus* remained the most abundant forbs, both increasing in average cover by 1.7%, while *Muhlenbergia sobolifera* remained the most abundant grass, increasing by >2x (Figure 22; Appendix 34). Increases in these species were greatest in the cut-herbicide and cut-burn treatments, where increase in total cover was greatest and cover for these species was highest prior to treatment.

Most herbaceous species with substantial increases in cover were prominent prior to treatment. Four exceptions, however, were *Erechtites hieracifolia*, *Glandularia canadensis* and *Verbascum thapsus*, all absent prior to treatment, and *Poinsettia dentata*, of negligible cover prior to treatment. All are disturbance-related species which became prominent in one or more of the cut treatments (Figure 22; Appendix 34). *Poinsettia dentata* became prominent in both cut treatments, *V. thapsus* became prominent in the cut-burn treatment, and *E. hieracifolia* and *G. canadensis* had notable cover in the cut-herbicide and cut-burn treatments, respectively. *Erechtites hieracifolia* and *P. dentata* are annuals, *V. thapsus* is a non-native biennial and *G. canadensis* is a perennial. As many as 20 of the 31 new species present following treatment were disturbance-related and 14 of the 31 species were annuals (Appendix 33).

Prairie/barrens species which were sampled for the first time included *Bouteloua curtipendula* and *Physostegia virginiana* in the cut-herbicide treatment, and *Sorghastrum nutans* in the cut-burn treatment (Appendix 33). Most of these species were probably present prior to treatment, but were neither conspicuous nor flowering.

<u>Glade.</u>

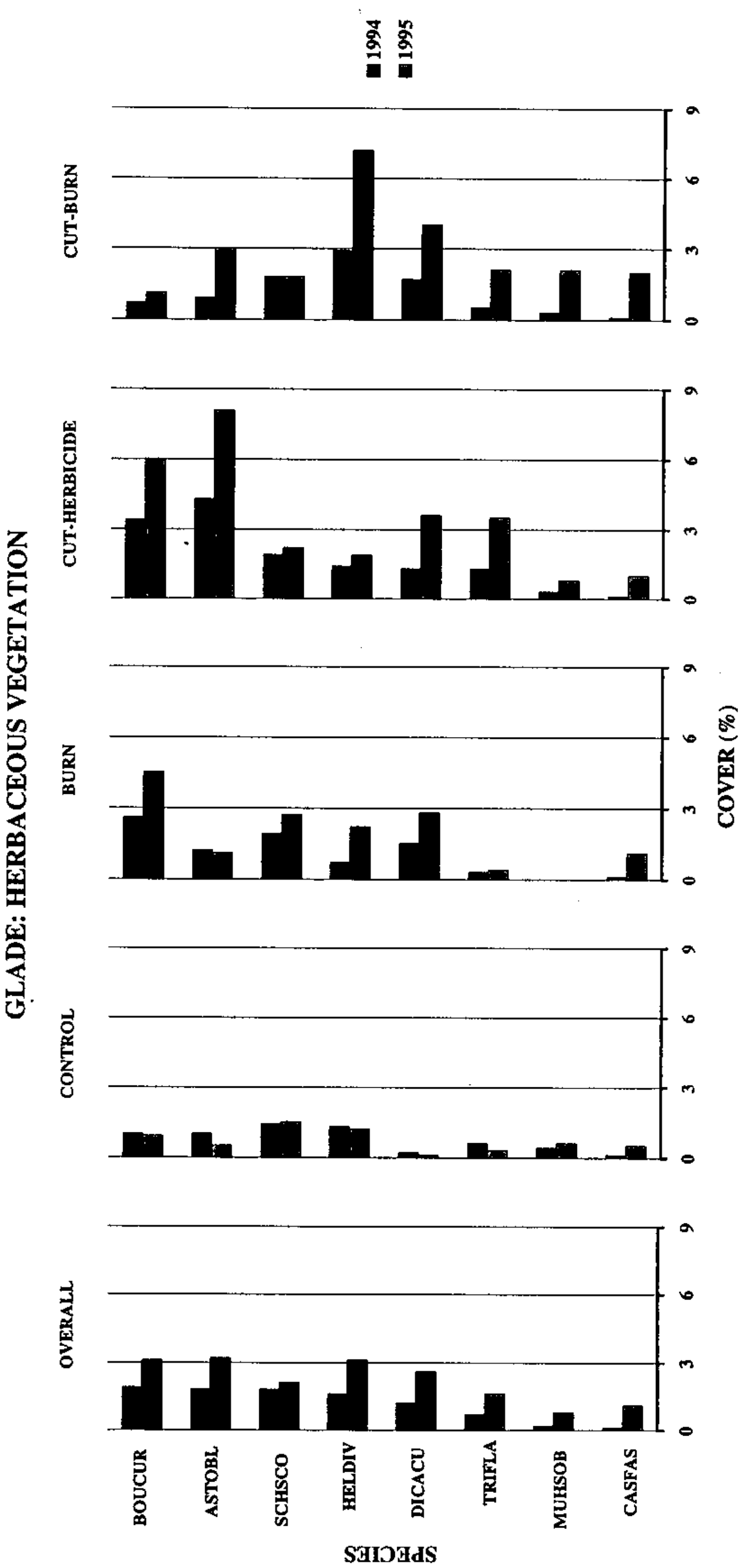
Seventy-three herbaceous species occurred within the glade in 1994, increasing to 77 species in 1995, of which 11 species were new (Table 9; Appendix 35). Prior to treatment, total cover of herbaceous vegetation within the glade was 14.5% (Table 9). *Bouteloua curtipendula* was the most abundant herbaceous species within the glade, with average cover of 1.9%, followed by *Aster oblongifolius* and *Schizachyrium scoparium* (1.8% each), *Helianthus divaricatus* (1.6%), *Dichanthelium acuminatum* (1.2%), and *Tridens flavus* (0.7%; Figure 23; Appendix 36).

Table 9. Mean cover and diversity indices for glade herbaceous vegetation and change in cover with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Species total cover represents the sum of species cover (including overlap). Standard deviations are in italics.

Variable	Year/Change	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
Species total cover (%)	1994	14.5	11.3	13.0	20.1	13.7
		7.1	*4.2*	*8.3*	*7.8*	*6.8*
	1995	26.4	10.2	21.7	40.2	33.6
		15.6	*3.3*	*15.8*	*13.5*	*8.6*
	Change	+11.9	-1.1	+8.7	+20.1	+19.9
Total number of species (*S*)	1994	73	44	42	41	44
	1995	77	44	47	47	46
Mean species richness (*S*/*n*)	1994	22.3	25.5	21.8	20.5	21.5
	1995	24.0	22.2	26.2	24.2	23.2
Shannon's index (*H*')	1994	3.13	3.13	2.83	2.72	2.88
	1995	3.13	3.09	2.88	2.83	2.87
Evenness (*E*)	1994	0.73	0.83	0.76	0.73	0.76
	1995	0.72	0.82	0.75	0.74	0.75

Total cover of herbaceous vegetation increased within the glade from 1994 to 1995 by 11.9% to 1.8x the pretreatment amount (Table 9; Figure 15). Total herbaceous cover increased most in the cut-herbicide treatment, where pretreatment cover was greatest, followed by increases in the cut-burn and burn treatments.

Figure 23. Change in cover for prominent glade herbaceous species. BOUCUR = *Bouteloua curtipendula*, ASTOBL = *Aster oblongifolius*, SCHSCO = *Schizachyrium scoparium*, HELDIV = *Helianthus divaricatus*, DICACU = *Dichanthelium acuminatum*, TRIFLA = *Tridens flavus*, MUHSOB = *Muhlenbergia sobolifera*, and CASFAS = *Cassia fasciculata*.


GLADE: HERBACEOUS VEGETATION
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
1994
1995
COVER (%)
0
3
6
9
SPECIES
BOUCUR
ASTOBL
SCHSCO
HELDIV
DICACU
TRIFLA
MUHSOB
CASFAS

Burning increased total herbaceous cover by 8.7% (a 67% increase; Table 9; Figure 15). *Bouteloua curtipendula* remained the most abundant herbaceous species, increasing by 1.9%, followed by *D. acuminatum* (+1.3%), *S. scoparium* (+0.8%), *H. divaricatus* (+1.5%), and *Cassia fasciculata* (+1.0%) from minimal (0.1%) cover (Figure 23).

The cut-herbicide treatment doubled total herbaceous cover (+20.1%; Table 9; Figure 15). *Aster oblongifolius* remained the most abundant herbaceous species, increasing by 3.8%, followed by *B. curtipendula* (+2.6%), *D. acuminatum* (+2.3%) and *T. flavus* (+2.2%; Figure 23; Appendix 36). Other species with increases >1.0% were *Croton monanthogynus* (+1.5%), *Sporobolus vaginiflorus* (+1.4%) from minimal (0.1%) cover and *Aristida longispica* (+1.1%). *Schizachyrium scoparium* increased by 0.3%.

Cutting and burning more than doubled total herbaceous cover (+19.9%; Table 9; Figures 15, 16 and 17). *Helianthus divaricatus* remained the most abundant herbaceous species, increasing by 4.3%, followed by *D. acuminatum* (+2.3%), *A. oblongifolius* (+2.1%), *T. flavus* (+1.6%), *M. sobolifera* (+1.8%), and *Cassia fasciculata* (+1.9%) from minimal (0.1%) cover (Figure 23). *Bouteloua curtipendula* increased by 0.4%, while *Schizachyrium scoparium* showed no change.

In the glade, herbaceous species richness (*S/n*) increased 8% while total herbaceous cover increased 82% with cutting and burning (Table 9). *Aster oblongifolius* and *Helianthus divaricatus* remained the most abundant forbs, increasing in average cover by 1.4% and 1.5%, respectively (Figure 23; Appendix 36). *Aster oblongifolius* increased most in the cut-herbicide treatment where it was most abundant prior to treatment, while *Helianthus divaricatus* increased most in treatments involving burning, regardless of pretreatment cover. *Bouteloua curtipendula* remained the most abundant grass within the glade, increasing in average cover by 1.2%, while *Dichanthelium acuminatum* and *Tridens flavus* more than doubled (+1.4% and +0.9%, respectively), surpassing *Schizachyrium scoparium* in cover in the cut-herbicide and cut-burn treatments. *Schizachyrium scoparium* increased relatively little (+0.3%), thus decreasing in prominence within the glade. Most herbaceous species with substantial increases in cover were prominent prior to treatment. One exception was *Cassia fasciculata* which increased notably from minimal cover in all three treatments, increasing most in the cut-burn treatment.

Bouteloua curtipendula and *Schizachyrium scoparium* increased in average flowering culm density with cutting and burning by 1.6 culms/m^2 and 0.1 culms/m^2, respectively (Figure 24). *Bouteloua curtipendula* had greater increases than did *S. scoparium* in flowering culm density, increasing most in the cut-herbicide treatment (+4.4 culms/m^2), where *B. curtipendula* cover increased most. Change in flowering culm density and cover followed similar patterns within and among treatments for *B. curtipendula* but not for *S. scoparium* (Figures 23 and 24).

Barrens and glade ordination.

The first ordination axis of DCA separated glades from barrens, representing a soil moisture gradient (Figure 25). All but two glade plots, which occurred near the edge of the glade, were clustered together. The second ordination axis represented a disturbance gradient within the barrens. Lower slope cut treatment plots with high canopy cover, particularly of *Acer saccharum*, and low herbaceous cover prior to treatment showed the strongest shift toward the disturbance end of the gradient, where large increases in disturbance-related species such as *Verbascum thapsus* and *Poinsettia dentata* occurred. Other barrens plots stayed clustered around the prominent woodland herbs, *Solidago ulmifolia* and *Helianthus divaricatus*. Glade plots showed little movement, reflecting the stability of species composition with treatment. An exception was plot 26, a glade edge plot, which showed a shift away from the barrens and toward the glade.

Environmental Variables

Barrens.

Overall within the barrens, litter was the only decreasing environmental cover variable (-4.1%), while exposed rock, bare soil and moss cover increased (Figure 26). The decrease in the

Figure 24. Change in flowering culm density for *Bouteloua curtipendula* and *Schizachyrium scoparium* in the glade. P = density present at <0.05 culms/m^2.

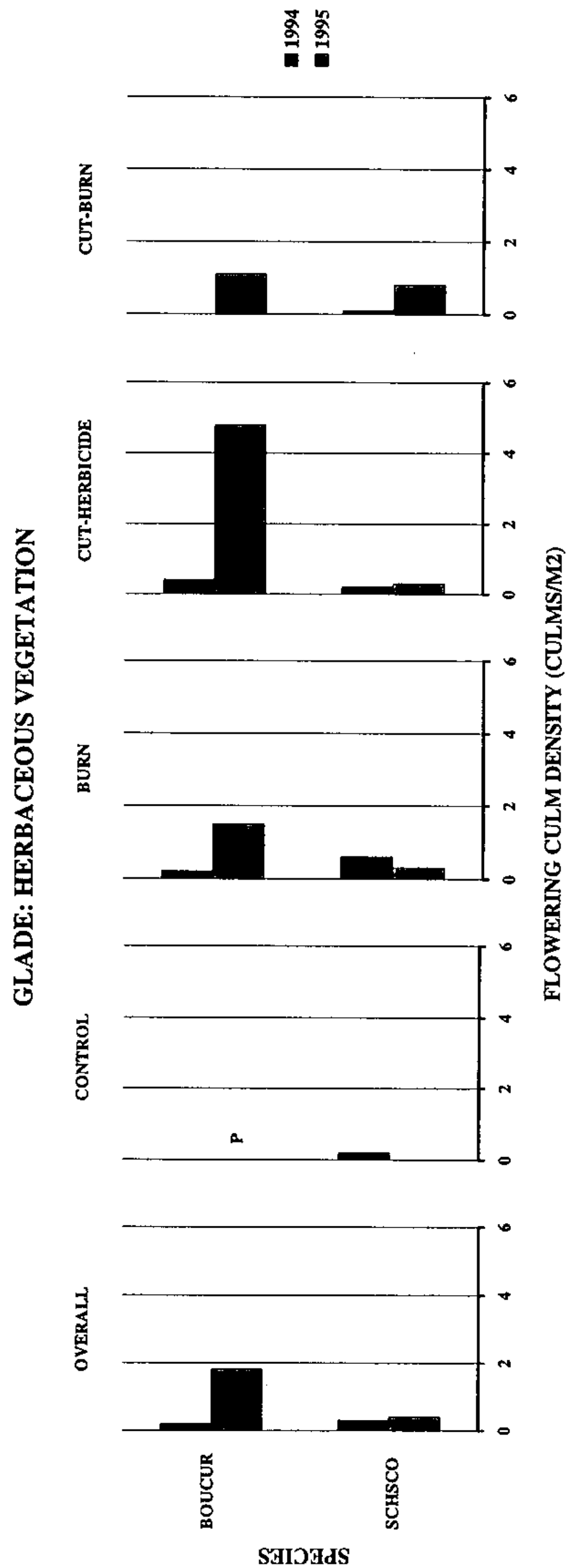

GLADE: HERBACEOUS VEGETATION
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
P
1994
1995
0
2
4
6
BOUCUR
SCHSCO
SPECIES
FLOWERING CULM DENSITY (CULMS/M2)

Figure 25. DCA (Detrended Correspondence Analysis) plot ordination for the barrens and glade at Fults Hill Prairie Nature Preserve before (4) and after (5) treatment. Letters following the year represent upper (U) and lower (L) barrens (B) and glade (G) plots in the burn (BO), cut-herbicide (CH) or cut-burn (CB) treatments. Plot numbers follow. Glade plots are circled. Note that the upper barrens plots, located in the lower left corner, are separated from lower barrens plots. Barrens and glade herbaceous species shown are those which increased in overall cover by $\geq$0.5% and $\geq$0.9%, respectively. Species locations are approximate. Trajectory arrows emphasize plots with the greatest change. Plots which moved little were not given arrows to minimize clutter.

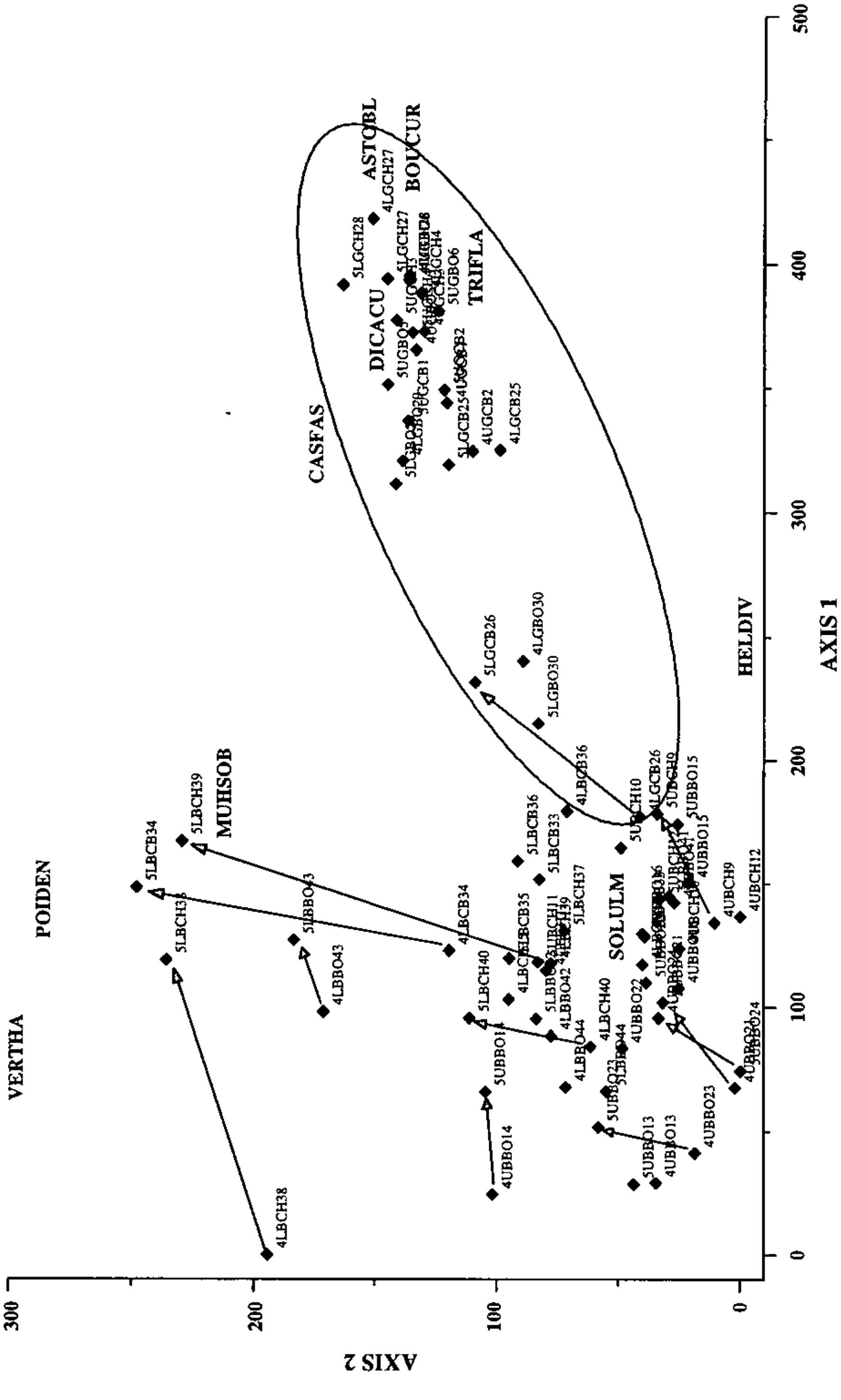
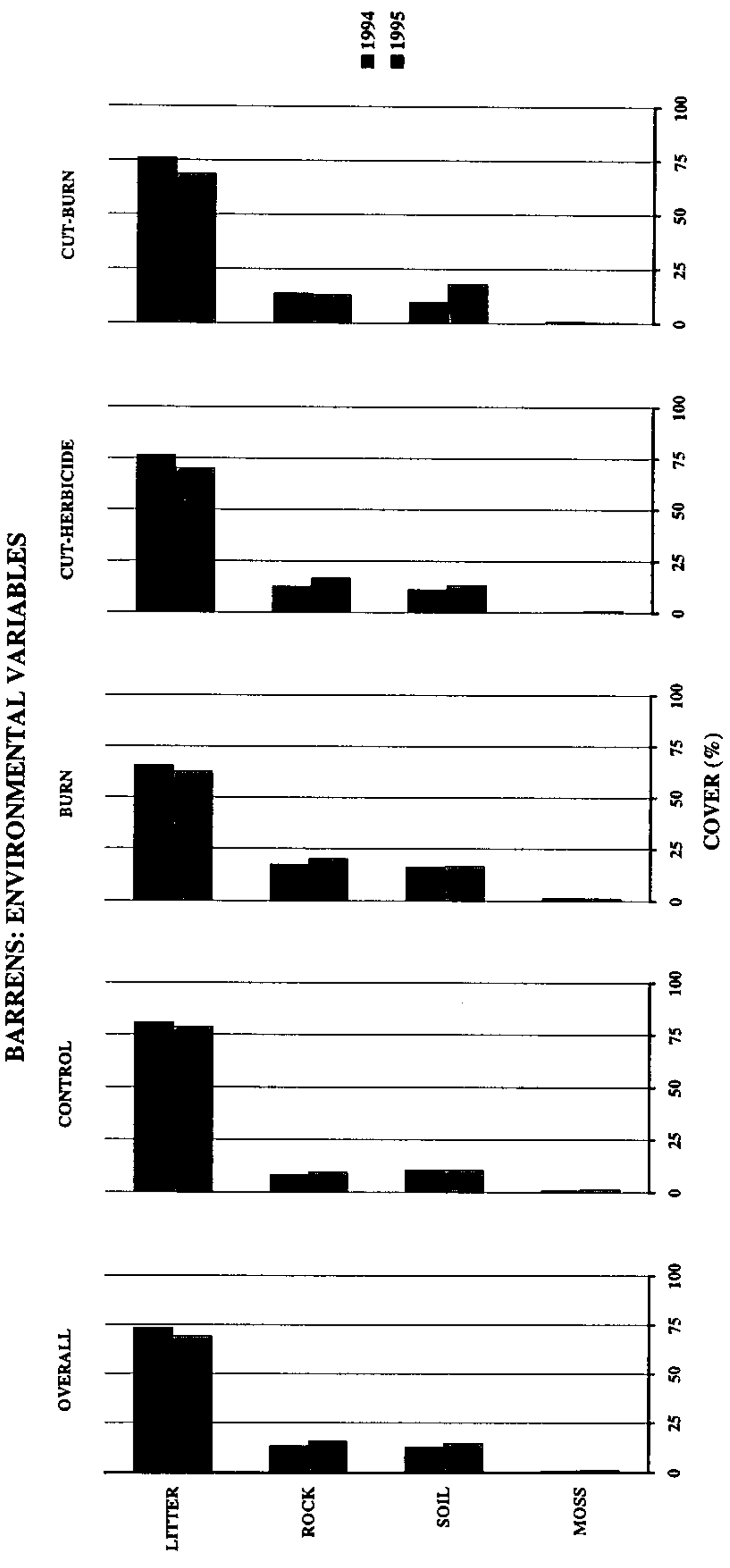

AXIS 1
AXIS 2
0
100
200
300
400
500
VERTHA
POIDEN
MUHSOB
SOLULM
HELDIV
CASFAS
DICACU
ASTOBL
BOUCUR
TRIFLA

Figure 26. Change in cover for barrens environmental variables.


BARRENS: ENVIRONMENTAL VARIABLES
1994
1995
OVERALL
CONTROL
BURN
CUT-HERBICIDE
CUT-BURN
LITTER
ROCK
SOIL
MOSS
0
25
50
75
100
COVER (%)

standing dead and down component of litter was probably greater than that indicated by the variable litter, since litter also included live vascular plant material, such as herbaceous vegetation and woody regeneration which increased in all treatments. The general pattern of decreasing non-living vegetation cover and increasing substrate cover was repeated throughout the treatments. Litter decreased in cover more than any other variable in all treatments, being the only decreasing variable in the cut-herbicide treatment, with the cut-herbicide and cut-burn treatments resulting in the largest litter decreases (-6.3% and -7.3%, respectively). Variables with the greatest increases in cover were exposed rock in the burn (+2.8%) and cut-herbicide (+4.0%) treatments, and bare soil (+8.3%) in the cut-burn treatment. Moss cover increased in the cut-herbicide treatment and decreased in the two burn treatments.

Glade.

Overall within the glade, litter decreased more than any other environmental cover variable (-1.3%), while exposed rock was the only increasing variable (+1.8%; Figure 27). In all treatments, litter cover decreased, while substrate cover increased. Litter decreased more than any other variable in the burn (-7.2%) and cut-burn (-1.1%) treatments, while exposed rock increased more than any other variable in the burn (+3.7%), cut-herbicide (+1.6%) and cut-burn (+1.4%) treatments. As with the barrens, the decrease in the down and standing dead component of litter was probably greater than indicated by the variable litter. Moss cover decreased in all treatments except the burn treatment where it showed no change.

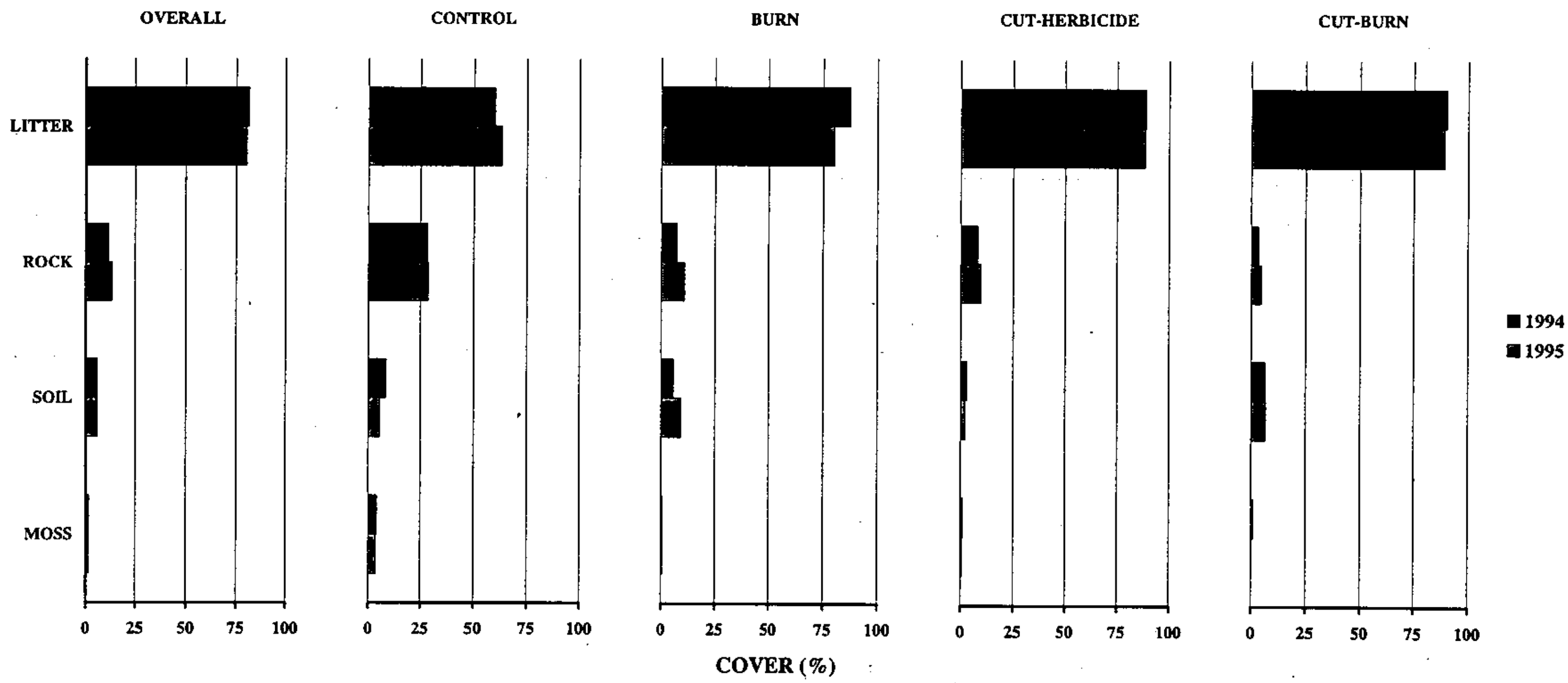
Ingrowth Age

Barrens.

From the barrens, stump sections from 36 hardwoods were aged (Appendix 37). Hardwood species examined included *Quercus prinoides, Fraxinus americana, Acer saccharum,* and *Carya texana*. Hardwoods ranged in dbh from 5.0 cm to 16.5 cm, with a mean diameter of 8.2 cm ± 2.7 cm, and in age from 28 to 41 years old, with a mean age of 36.6 years ± 3.5 years.

Figure 27. Change in cover for glade environmental variables.

GLADE: ENVIRONMENTAL VARIABLES



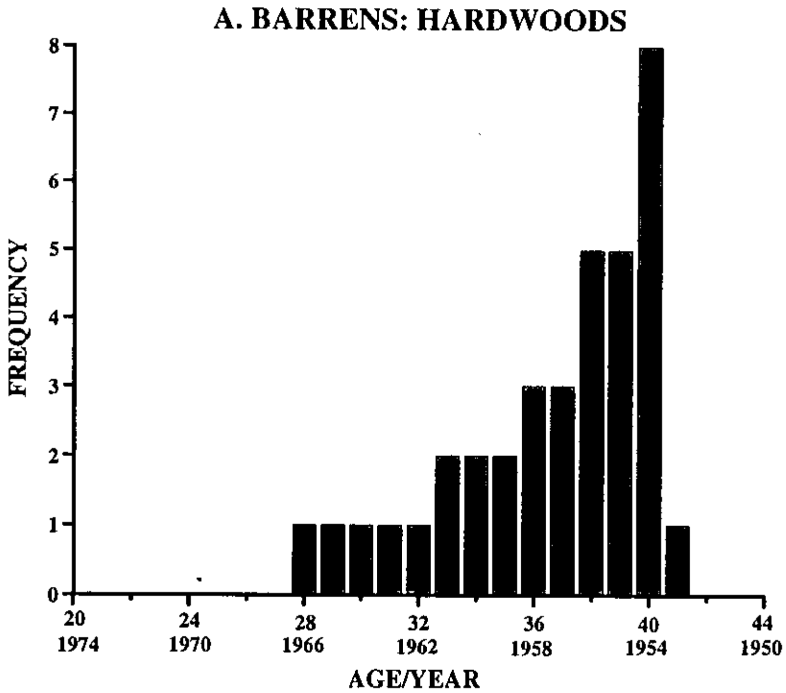
The age distribution for hardwoods appeared to indicate a flush of recruitment occurred in the barrens about 40 years ago (1954; Figure 28A). Only one tree collected at the site was found to have a fire scar: an 84 year old *J. virginiana* from the barrens with a scar dating to 1953 (41 years ago). This coincides with one of the two possible years Francis Heller, the adjacent landowner, indicated that a fire occurred on the site, as documented earlier in the study site description. Lack of fire is one possible explanation for the pattern of recruitment seen. Other possibilities include fluctuations in weather patterns or changes in land use practices, such as initiation of grazing. No information was gathered concerning weather changes and known land use of the area during this period did not include grazing. Although only a limited range of size classes was collected for aging, size class distribution for aged hardwoods was similar to that for all hardwoods sampled in the barrens (Figure 28B).

Also from the barrens, 12 *Juniperus virginiana* were aged (Appendix 37). *Juniperus virginiana* ranged in dbh from 5.1 cm to 16.2 cm, with a mean diameter of 7.0 cm ± 3.1 cm, and in age from 23 to 84 years old, with a mean age of 38.1 years ± 20.1 years. The age distribution for *J. virginiana* in the barrens indicated a pattern of constant recruitment for this species (Figure 29A). Comparing the size class distribution of aged *J. virginiana* with that of all *J. virginiana* sampled, it appears that aged trees were over represented in size class 2 relative to the other size classes, particularly size class 3 (Figure 29B). Aging of additional trees might reveal a pattern more similar to barrens hardwood distribution (Figures 28 and 29).

Glade.

From the glade, stump sections from 15 *Juniperus virginiana* were aged. *Juniperus virginiana* was the only ingrowth species examined within the glade and ranged in dbh from 5.2 cm to 13.5 cm, with a mean diameter of 8.3 cm ± 2.7 cm, and in age from 24 to 44 years, with a mean age of 33.1 years ± 5.7 years. The age distribution for *J. virginiana* in the glade, as in the barrens, indicated a pattern of relatively constant recruitment of this species (Figures 29A and

Figure 28. (A) Age distribution for barrens hardwood ingrowth and (B) size class distribution for aged hardwoods and all hardwoods sampled in the barrens. Data are for tree sized stems $\geq$5.0 cm dbh. Size class (dbh) ranges are C1 = to 2.5 cm, C2 = 2.6 - 6.5 cm, C3 = 6.6 - 11.6 cm, C4 = 11.7 - 16.7 cm, C5 = 16.8 - 21.8 cm, C6 = 21.9 - 26.9 cm, C7 = 27.0 - 31.9 cm, C8 = 32.0 - 37.0 cm, C9 = 37.1 - 42.1 cm, C10 = 42.2 - 47.2 cm, C11 = 47.3 - 52.3 cm, C12 = 52.4 - 62.4 cm, C13 = 62.5 - 67.5 cm, and C14 = 67.6 - 72.6 cm.


A. BARRENS: HARDWOODS
FREQUENCY
0
1
2
3
4
5
6
7
8
20
1974
24
1970
28
1966
32
1962
36
1958
40
1954
44
1950
AGE/YEAR

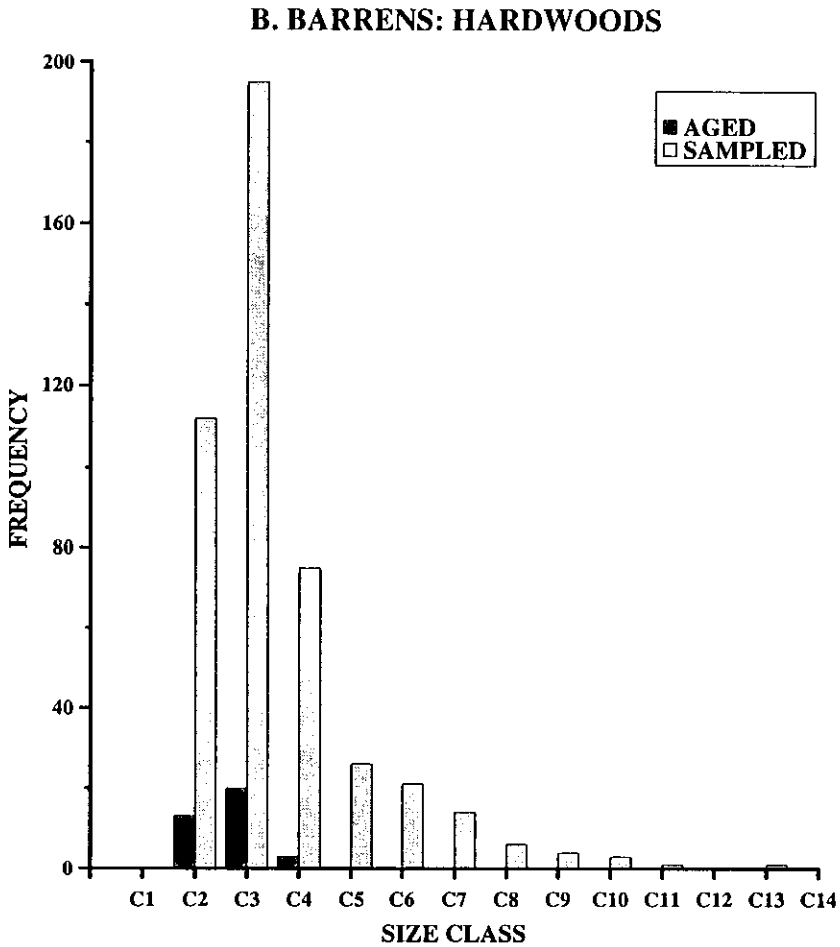
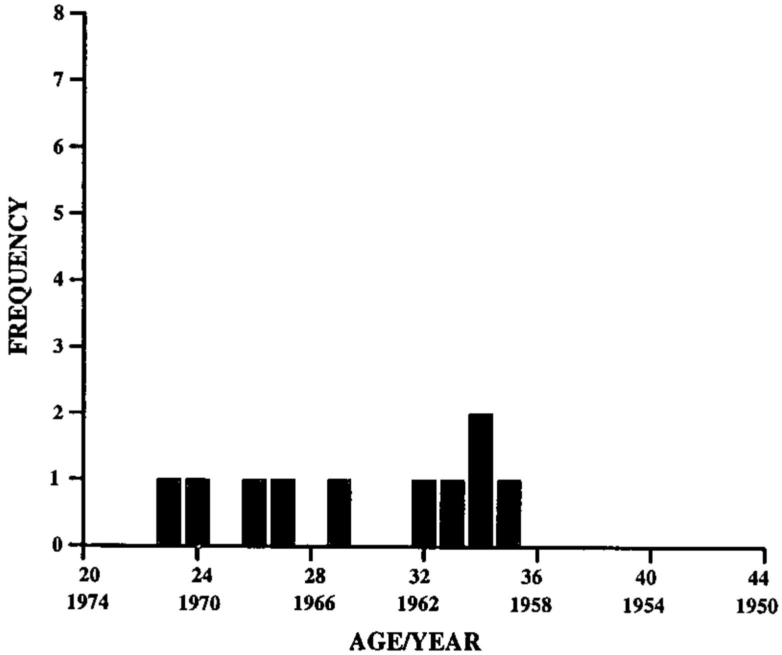
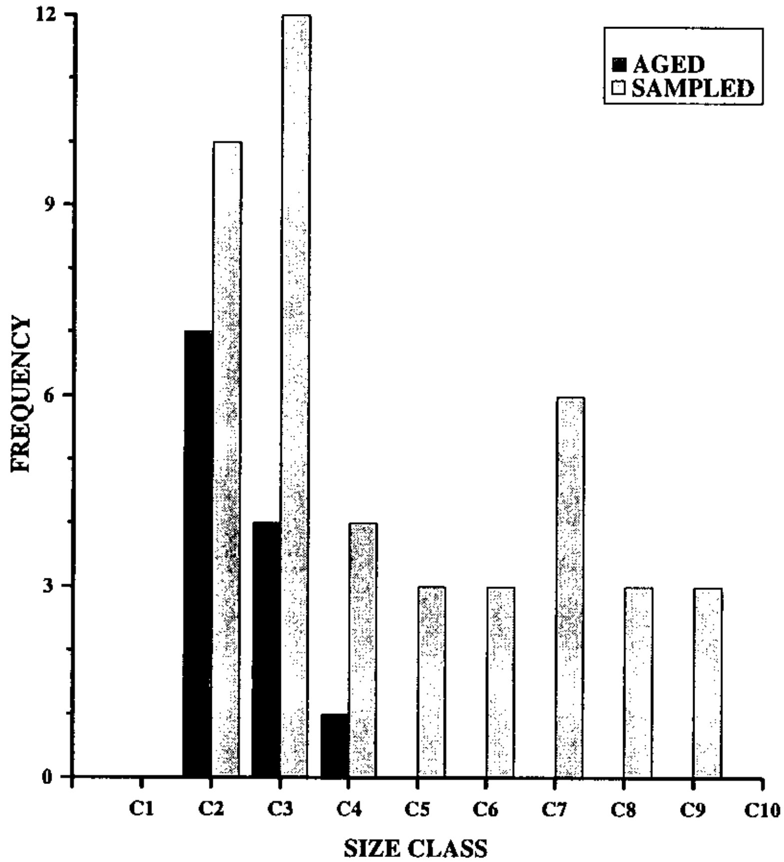

B. BARRENS: HARDWOODS
AGED
SAMPLED
FREQUENCY
0
40
80
120
160
200
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
SIZE CLASS

Figure 29. (A) Age distribution for *Juniperus virginiana* ingrowth in the barrens. Two additional stems, aged 76 and 84 years old, dating to 1918 and 1910, respectively, are not pictured. (B) Size class distribution for aged *J. virginiana* [including the two stems not pictured in (A)] and all *J. virginiana* trees sampled in the barrens. Data are for tree sized stems ≥5.0 cm dbh. Size class (dbh) ranges are C1 = to 2.5 cm, C2 = 2.6 - 6.5 cm, C3 = 6.6 - 11.6 cm, C4 = 11.7 - 16.7 cm, C5 = 16.8 - 21.8 cm, C6 = 21.9 - 26.9 cm, C7 = 27.0 - 31.9 cm, C8 = 32.0 - 37.0 cm, C9 = 37.1 - 42.1 cm, and C10 = 42.2 - 47.2 cm.

A. BARRENS: JUNIPERUS VIRGINIANA

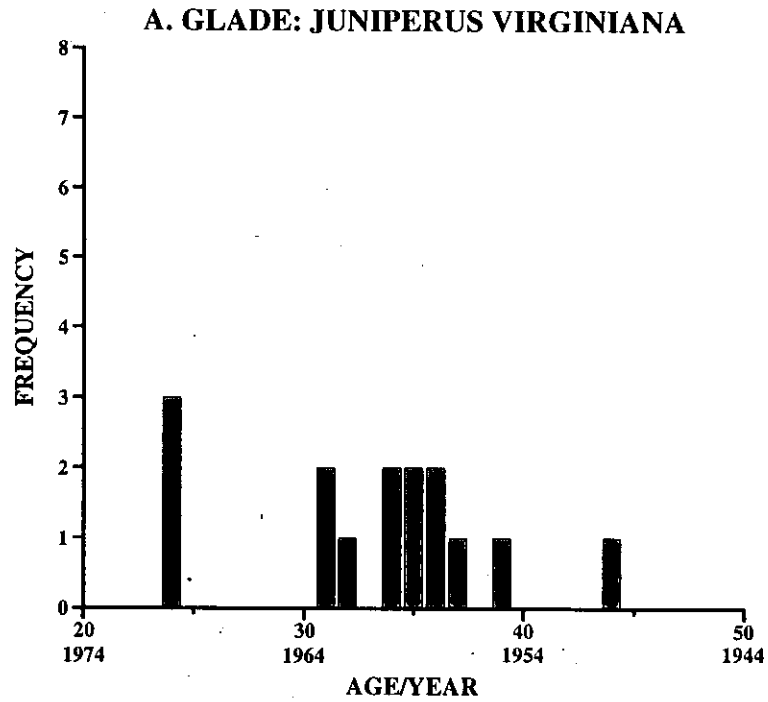


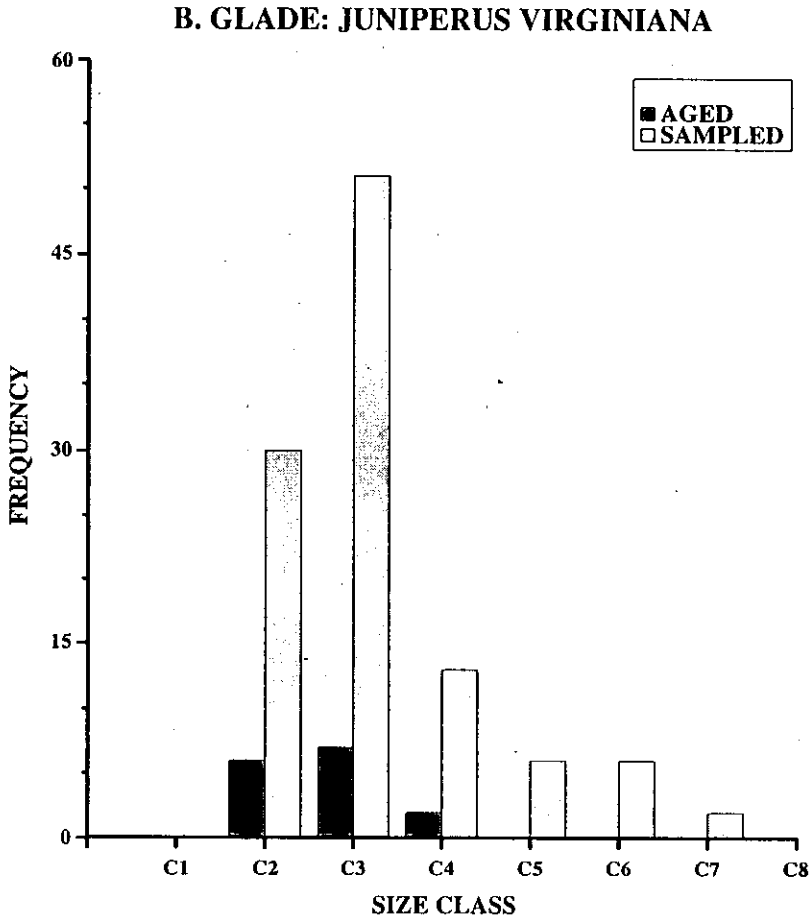
B. BARRENS: JUNIPERUS VIRGINIANA



30A). However, the size class distribution of aged *J. virginiana* does not adequately represent stems in size class 3 (Figure 30B). Aging of additional stems may reveal a pattern more similar to barrens hardwood distribution (Figures 28 and 30).

Figure 30. (A) Age distribution for *Juniperus virginiana* ingrowth in the glade and (B) size class distribution for aged *J. virginiana* and all *J. virginiana* trees sampled in the glade. Data are for tree sized stems ≥5.0 cm dbh. Size class (dbh) ranges are C1 = to 2.5 cm, C2 = 2.6 - 6.5 cm, C3 = 6.6 - 11.6 cm, C4 = 11.7 - 16.7 cm, C5 = 16.8 - 21.8 cm, C6 = 21.9 - 26.9 cm, C7 = 27.0 - 31.9 cm, and C8 = 32.0 - 37.0 cm.


A. GLADE: JUNIPERUS VIRGINIANA
FREQUENCY
0
1
2
3
4
5
6
7
8
20
1974
30
1964
40
1954
50
1944
AGE/YEAR


B. GLADE: JUNIPERUS VIRGINIANA
AGED
SAMPLED
FREQUENCY
0
15
30
45
60
C1
C2
C3
C4
C5
C6
C7
C8
SIZE CLASS

DISCUSSION

Treatment Effects: Barrens

Woody vegetation.

In this study, barrens tree basal area, density, total cover, and total number of species decreased with cutting, but were unaffected by burning. Anderson and Schwegman (1971), Heikens et al. (1994), White (1983), and Kline and McClintock (1994), studying prescribed burning effects on southern Illinois barrens, southwestern Illinois barrens, Minnesota oak savanna, and Wisconsin dry oak forest, respectively, found similarly that burning alone was insufficient to reduce woody stems in larger size classes. The ability of burning to reduce tree-sized stems tends to increase with repeated burning (Tester 1989) and greater fire intensity (Cole et al. 1990) and is dependent on stem diameter.

Cutting and burning were both effective means of reducing barrens sapling/shrub density and cover. Total number of species decreased with treatment as well. Out of the three treatments, only one species, *Quercus rubra*, increased in only the cut-burn treatment, as a result of sprouts which grew into the sapling size class. Numerous studies have cited reductions in saplings and shrubs with burning (Anderson and Schwegman 1971, White 1983, Kline and McClintock 1993, Kline and McClintock 1994). Often shrub species remain in the community, but are represented as sprouts (White 1983, Nuzzo et al. 1996).

Barrens regeneration density, cover and total number of species increased in response to cutting and burning, except for burn treatment cover which showed no change. Considering the substantial increase in burn density, lack of change in burn cover is likely the combined result of increased number but decreased cover of individual stems, as well as shifts in prominent species. *Rhus aromatica*, the dominant regeneration species, increased substantially in density with cutting and burning, yet decreased or showed no change in cover. Axelrod and Irving (1978) and Nuzzo et al. (1996), examining prescribed fire effects in Minnesota sand savanna and central Illinois sand forest, respectively, reported similar findings, noting that while shrub cover was little reduced with burning, shrub height decreased. Nuzzo et al. noted, however, that after one year without burning, shrub sprouts exceeded 2 m in height.

Sprouting of cut trees and shrubs accounted, in part, for the greater increase in regeneration density and cover in the cut-burn treatment, relative to the cut-herbicide and burn treatments. *Acer saccharum* and *Viburnum rufidulum* were two species with numerous sprouts in the cut-burn treatment. Sprouts of *A. saccharum* were confined to a single 1 m^2 plot. *Acer saccharum* was reduced in regeneration density and cover in the other treatments, where herbiciding of cut stumps and more complete burn coverage were effective against sprouting. *Acer saccharum* is known to be intolerant of fire (Apfelbaum and Haney 1989, Abrams 1992, Heikens et al. 1994). The presence and removal of a larger number of *V. rufidulum* shrubs in the cut-burn treatment, along with minimal fire coverage (only 10% of the area burned), accounted for the much larger number of *V. rufidulum* sprouts in this treatment relative to other treatments. No explanation is offered for the decrease in *Quercus prinoides* regeneration in all treatments with cutting and burning. The literature supports ample sprouting of *Quercus* species when top-killed (Thor and Nichols 1974, Lorimer 1985, Ross et al. 1986).

Three woody vines, *Parthenocissus quinquefolia*, *Toxicodendron radicans* and *Vitis cinerea*, increased significantly in density and cover with cutting and burning. *Parthenocissus quinquefolia* is reported to decrease with burning (Heikens et al. 1994, Nuzzo et al. 1996), while *T. radicans* is reported to both increase (White 1983, Heikens et al. 1994) and decrease (Nuzzo et al. 1994) with burning. Apfelbaum and Haney (1989) mentioned *Vitis* among the ground cover species which increased following an autumn burn in an oak savanna remnant.

Herbaceous vegetation.

Total herbaceous species cover and total number of herbaceous species increased in the barrens with both cutting and burning. Herbaceous species increased >3x as much with cutting, either with or without burning, than with burning alone. *Solidago ulmifolia, Helianthus divaricatus* and *Muhlenbergia sobolifera,* species prominent prior to treatment, increased most. All three species are common to rocky woodlands (Steyermark 1981, Mohlenbrock 1986) and their occurrence at Fults is described by Ozment (1967). *Helianthus divaricatus,* a rhizomatous perennial which may form dense colonies to the exclusion of other vegetation (Anderson and Liberta 1987, McCall 1995), is prevalent in Illinois barrens (Madany 1981). Species of *Solidago* and *Helianthus* often respond positively to burning (DeSelm et al. 1974, White 1983, Schwegman and Anderson 1986). Bittner et al. (1994) cited *H. divaricatus* as the characteristic herbaceous species of the uncut portion of a southern Illinois shale barrens following two burns. Apfelbaum and Haney (1989), studying fire effects on degraded oak savanna remnants in northern Illinois, found that *S. ulmifolia,* present prior to treatment, increased immediately with the initiation of burning. In studies of two separate southern Illinois barrens, Heikens et al. (1994) noted a significant increase in *M. sobolifera* cover following a spring burn. Bittner et al. (1994), further studying one of these barrens, reported significantly higher *M. sobolifera* cover in the burned portion of the barrens relative to the cleared and burned portion. Anderson and Schwegman (1991) found *M. sobolifera* frequency was lower after 2 fires than at 15 years postburn. Nuzzo et al. (1996) noted that a single forest species, *Eupatorium rugosum,* while low in cover prior to treatment, had greater cover than any other native herbaceous species and increased most with burning of a sand forest. Their study noted that forest herbaceous species increased more with burning than did prairie species, attributing this finding to loss of prairie species due to the absence of fire.

Another group, disturbance-related species, particularly annuals, increased substantially in richness and cover with cutting and burning in the lower slope cut-burn and cut-herbicide treatments. Increase in annual species occurrence is common following disturbance (Nuzzo et al. 1996), especially on bare soil. Disturbance-related species encountered for the first time following treatment in this study which where found in the soil seed bank of a southern Illinois shale barrens (McCall et al. 1998) were *Conyza canadensis*, *Erigeron annuus*, *Lactuca serriola*, *Phytolacca americana*, and *Verbascum thapsus*. Johnson and Anderson (1986), in a study of tallgrass prairie in Illinois, noted that weedy plant species were more abundant in the seed bank than would be expected from their abundance in the vegetation.

Several prairie/barrens species, probably present prior to treatment, were sampled for the first time following treatment. Likewise, Heikens et al. (1994) and Kline and McClintock (1993) found previously unrecorded prairie and barrens species present following burning. Stritch (1990*a*) noted the presence of several barrens species for the first time following cutting and burning, but did not see as great an effect with burning only. In the current study, presence of new barrens species was more apparent with cutting, either with or without burning, than with burning alone, likely due to greater canopy reduction and treatment placement.

Treatment Effects: Glade

Woody vegetation.

As in the barrens, glade tree basal area, density and total cover decreased with cutting, but were unaffected by burning, while sapling/shrub density and cover decreased with both cutting and burning. Trees and saplings of *Juniperus virginiana*, the dominant species, were eliminated with cutting, while burning affected only *J. virginiana* saplings, decreasing density by 20%. Similarly, Abrell (1990) found that spring burns were insufficient to eliminate *J. virginiana* >4 cm in basal diameter, while Anderson and Schwegman (1991) noted an absence of sapling/seedling size *J. virginiana* following burning. Other sapling/shrub species, including *Rhus aromatica*, *R. copallina* and *Cornus drummondii*, also decreased in the burn treatment. See barrens sapling/shrub discussion for related research citations.

Rhus aromatica, the dominant regeneration species, increased in density, but decreased in cover, as in the barrens (except in the burn treatment, where cover increased). See barrens regeneration discussion of *R. aromatica* for related research citations. *Rhus copallina* increased in regeneration density and cover in all three treatments, responding most to burning. Hutchison (1992) noted that burning in the early spring could increase the sprouting and spread of a closely related species, *Rhus glabra*. Bacone and Post (1986) reported that sprouting maintained *R. glabra* frequency after four burns in a black oak sand savanna.

Herbaceous vegetation.

Total herbaceous species cover and total number of species increased in the glade with both cutting and burning. Herbaceous species increased >2x as much with cutting, either with or without burning, than with burning alone. Burning and cutting increased grass species cover, but did not necessarily favor the typical glade dominants *Schizachyrium scoparium* and *Bouteloua curtipendula* over other grass species such as *Dichanthelium acuminatum*, *Tridens flavus* and *Muhlenbergia sobolifera*. The low response of *Schizachyrium scoparium* cover to burning is consistent with findings in the literature. Despite this species prominence in fire dependent communities, reported response of *S. scoparium* to burning varies widely (Tyndall 1994). Tyndall found no significant response by *S. scoparium*, the community dominant, to either cleared-only or cleared-and-burned treatments in a Maryland Serpentine barrens. Response of *M. sobolifera* to burning also reportedly varies, as discussed under barrens herbaceous vegetation (Anderson and Schwegman 1991, Bittner et al. 1994, Heikens et al. 1994). Heikens et al. (1994) noted that *T. flavus*, absent in preburn sampling, was present after burning in two southern Illinois barrens. Bittner et al. (1994) found that cover for both *D. acuminatum* and *T. flavus* was significantly higher in a cleared and burned barrens relative to a portion of the barrens which was only burned.

Burning and cutting increased forb species cover, particularly that of *Aster oblongifolius* and *Helianthus divaricatus*, the most prominent glade forbs. *Aster oblongifolius* is a common species of limestone glades in western Illinois (Kurz 1981), while *H. divaricatus* is common to limestone glades throughout Illinois (Kurz 1981). *Helianthus divaricatus* increased most in treatments involving burning, with or without cutting. As noted previously, species of *Helianthus* often respond positively to fire (DeSelm et al. 1974, White 1983). Elsenheimer (1994) reported almost 50% greater biomass of *H. divaricatus* in burned than in unburned plots following 14 years of biennial burning on hill prairies in southern Illinois.

Most herbaceous species with substantial increases in cover were prominent prior to treatment, one exception being *Cassia fasciculata*, an annual legume with minimal cover prior to treatment. Anderson and Schwegman (1991) noted immediate large increases in frequency of *C. fasciculata* and *C. nictitans* following each of two burns, likely due to substantial soil seed banks. Frequency of these species declined rapidly following fire cessation.

Bouteloua curtipendula and *Schizachyrium scoparium* flowering culm density increased with cutting and burning, except for *S. scoparium* in the burn treatment. Flowering activity for both species is reported to increase with burning (Pemble et al. 1981). Pemble et al. (1981) noted greater flower culm production for both *B. curtipendula* and *S. scoparium* following burning of a dry-mesic south-facing prairie slope in northwestern Minnesota. Henderson et al. (1982) reported non-significant increases in *B. curtipendula* and *S. scoparium* flower production following a single spring burn on a dry prairie remnant in Wisconsin.

Recommendations for Management and Further Study

Continued restoration of the glade and barrens should include burning at a restoration level (i.e., a greater frequency than proposed for maintenance on the site/less than every three years). Change in prominent herbaceous species cover should be monitored and presence of previously unsampled prairie/barrens species should be noted following each burn, and this information should be used to plan future burning. In particular, change in cover of *Helianthus divaricatus* should be monitored, because this species has the potential to dominate the herbaceous cover of both the glade and the barrens, due to its colonial growth habit and positive response to fire. If necessary, steps should be taken to maintain *H. divaricatus* at comparable cover levels with other prominent glade and barrens herbaceous species. *Lonicera japonica*, located at the south edge of Plot 4 in the upper glade, should be treated with a combination of burning and herbiciding as recommended by the vegetation management guidelines for nature preserves (INPC 1990*c*).

Burning alone is not likely to affect tree-sized stems, reduce saplings and shrubs as effectively as cutting, nor reduce regeneration stem densities. Therefore, cutting, where needed, is recommended to selectively reduce tree, sapling/shrub and regeneration densities. Periodic mechanical removal of heavily sprouting species, such as *Rhus aromatica*, is recommended. Cut stems should be herbicided if continual removal of sprouts is not effective.

An additional portion of upper barrens west of the study site contains prairie plants in the understory and should be included in the restoration process. A portion of the lower glade (plots 27 and 28), which was part of the cut-herbicide treatment, exemplifies the character of the glades which occur between the margins of the hill prairies and the edges of the bluff tops at Fults. This portion of the glade appears to be least susceptible to woody encroachment due to the presence of extremely thin soils and may require little or no management. *Allium stellatum*, *Rudbeckia missouriensis* and *Galium virgatum* occur only on this portion of the glade. The bluff top glades, which have been managed in conjunction with the hill prairies at Fults for a number of years, should be used as a guideline for management of this part of the glade.

Due to the minimal response of prairie species to management in the barrens, further investigation should include a study of this community's soil seed bank to determine prairie species presence. Similar study of the glade soil seed bank where cedars occurred may be beneficial, as well, if prairie vegetation is slow to reoccupy these areas. Characterization of soils may shed light on differences between glade and barrens vegetation and differences in vegetation within the glade, which may alter management objectives. Further age determination studies focusing on saplings and larger trees would provide greater insight into recruitment and fire history on the site. Finally, while visual estimation of changes in prairie species cover, relative to other species, may suffice for making management decisions year to year, it is recommended that this study be repeated following a number of years of consistent restoration management to determine long-term management effects.

CONCLUSION

Change in basal area, density and/or cover for woody and herbaceous vegetation was compared for three treatments: (a) burn, (b) cut-herbicide and (c) cut-burn, in both a limestone glade and a degraded barrens. Barrens and glade tree basal area, density and total cover decreased with cutting, but were unaffected by burning, while sapling/shrub density and cover decreased with both cutting and burning. Barrens regeneration density and cover increased with cutting and burning, as did glade regeneration density, while glade regeneration cover decreased, except in the burn treatment. Herbaceous cover increased with cutting and burning in both the glade and the barrens.

Barrens restoration resulted in substantial reductions in tree basal area in the cut-herbicide (-49%) and cut-burn (-48%) treatments, increasing relative dominance of *Quercus prinoides* in the overstory, and substantial reductions in sapling/shrub density in the burn (-53%), cut-herbicide (-59%) and cut-burn (-91%) treatments. In response, regeneration density increased in the burn (+58%), cut-herbicide (+65%) and cut-burn treatments (+167%), primarily from increases in the dominant shrub, *Rhus aromatica*, and three woody vines, *Parthenocissus quinquefolia*, *Toxicodendron radicans* and *Vitis cinerea*, and herbaceous cover increased in the burn (+82%), cut-herbicide (+245%) and cut-burn (+392%) treatments. Herbaceous species with the greatest increases were woodland grasses and forbs prominent prior to treatment, particulary *Solidago ulmifolia*, *Helianthus divaricatus* and *Muhlenbergia sobolifera*. Disturbance-related herbaceous species increased notably in the cut treatments and several prairie/barrens species were sampled for the first time in the cut treatments following treatment.

Glade restoration resulted in substantial reductions in tree basal area in the cut-herbicide (-60%) and cut-burn (-99%) treatments, eliminating *Juniperus virginiana*, the dominant tree, from these treatments, and substantial reductions in sapling/shrub density in the burn (-29%), cut-herbicide (-64%) and cut-burn (-95%) treatments, eliminating *J. virginiana* from the two cut treatments. In response, regeneration density increased in the burn (+69%), cut-herbicide (+48%) and cut-burn (+102%) treatments, primarily from increases in the dominant shrub, *Rhus aromatica*, and *R. copallina*, and herbaceous cover increased in the burn (+67%), cut-herbicide (+100%) and cut-burn (+145%) treatments. Forbs with the greatest increases were *Aster oblongifolius* and *Helianthus divaricatus*, prominent species prior to treatment and *Cassia fasciculata*, an annual legume which responds positively to fire. Grasses with the greatest increases included *Bouteloua curtipendula*, a typical glade dominant, as well as *Dichanthelium acuminatum*, *Tridens flavus* and *Muhlenbergia sobolifera*. The later three grasses increased most in the cut treatments. *Schizachyrium scoparium* increased relatively little, if at all, with treatment.

Treatments involving cutting, either with or without burning, were more effective at reducing woody cover and increasing prairie/barrens species cover (or presence, for barrens) than was burning alone. Differences in species changes between the cut-herbicide and cut-burn treatments appear to be as much a result of differential abundance prior to treatment and unintentional differences in the level of cutting, as a result of differences in burning. However, some species, such as *Helianthus divaricatus* and *Rhus aromatica* do appear to respond specifically to burning, and burning is known to promote prairie/barrens herbaceous vegetation.

Restoration has moved the glade and barrens communities closer to their former structure, particularly in the two cut treatments. Compositional changes within these communities are slower to occur. Based on findings, it is recommended that restoration level burning (less than every three years), cutting and herbiciding continue to be used to restore the glade and barrens, accompanied by monitoring. The goal of further restoration should be the reduction or maintenance of woody species, the promotion of prairie/glade grass and forb species over other grass and forb species in the glade, and the promotion of prairie/barrens species over woodland and weedy species in the barrens. Additionally, in the glade, restoration should strive to achieve glade species cover values and glade species diversity similar to that found in the highest quality, managed glades at Fults. An exception to management recommendations is the most xeric, thin-soiled portion of the glade, which may require little or no management for maintenance.

LITERATURE CITED

Abrams, M. D. 1992. Fire and the development of oak forests. BioScience **42**:346-353.

Abrell, B. 1990. Control of eastern red cedar (*Juniperus virginiana*) by girdling and burning at Leavenworth Barrens Nature Preserve, Indiana. Natural Areas Journal **10**:140.

Aldrich, J. R., J. A. Bacone and M. D. Hutchison. 1982. Limestone glades of Harrison County, Indiana. Indiana Academy of Science **91**:480-485.

Anderson, E. 1989. Fults Hill Prairie Nature Preserve, 3-year management schedule. Illinois Department of Conservation, unpublished data.

Anderson, R. C. and L. E. Brown. 1983. Comparative effects of fire on trees in a midwestern savannah and an adjacent forest. Bulletin of the Torrey Botanical Club **110**:87-90.

Anderson, R. C. and A. E. Liberta. 1987. Variation in vesicular-arbuscular mycorrhizal relationships of two sand prairie species. American Midland Naturalist **118**:56-63.

Anderson, R. C. and J. E. Schwegman. 1971. The response of southern Illinois barren vegetation to prescribed burning. Transactions of the Illinois State Academy of Science **64**:287-291.

Anderson, R. C. and J. E. Schwegman. 1991. Twenty years of vegetational change on a southern Illinois barren. Natural Areas Journal **11**:100-107.

Apfelbaum, S. I. and A. W. Haney. 1989. Management of degraded oak savanna remnants in the upper midwest: preliminary results from three years of study. Pages 27-47 *in* Proceedings of the ninth northern Illinois prairie workshop.

Bacone, J. A., L. A. Casebere and M. D. Hutchison. 1983. Glades and barrens of Crawford and Perry counties, Indiana. Indiana Academy of Science **92**:367-373.

Bacone, J. A. and T. W. Post. 1986. Effects of prescribed burning on woody and herbaceous vegetation in black oak sand savanna at Hoosier Prairie Nature Preserve, Lake County, Indiana. Pages 86-90 *in* A. L. Koonce, editor. Prescribed burning in the midwest: state-of-the-art: proceedings of a symposium. College of Natural Resources, University of Wisconsin - Stevens Point, Stevens Point, Wisconsin.

Bagienski, F. F. 1979. The effect of a prescribed spring fire on four hill prairies in the Ozark region of southern Illinois: first year results. M. S. Thesis, Southern Illinois University Carbondale, Carbondale, Illinois.

Bartgis, R. L. 1993. The limestone glades and barrens of West Virginia. Castanea **58**:69-89.

Baskin, J. M. and C. C. Baskin. 1996. Bessey Picklesimer's little-known quantitative study on the vegetation of a cedar glade in the Central Basin of Tennessee. Castanea **61**:25-37.

Baskin, J. M., C. C. Baskin and E. W. Chester. 1994. The Big Barrens Region of Kentucky and Tennessee: further observations and considerations. Castanea **59**:226-254.

Beilmann, A. P. 1951. Wildlife as an indicator of land management. Missouri Botanical Garden Bulletin **39**:44-45.

Beilmann, A. P. and L. G. Brenner. 1951. The changing forest flora of the Ozarks. Annals of the Missouri Botanical Garden **38**:283-291.

Bittner, R. T., D. J. Gibson, R. K. McCall, and K. A. West. 1994. Vegetation analysis of a restored southern Illinois shale barrens. Pages 287-292 *in* J. S. Fralish, R. C. Anderson, J. E. Ebinger, and R. Szafoni, editors. Proceedings of the North American conference on barrens and savannas. The Environmental Protection Agency, Great Lakes National Program Office.

Bordeau, P. 1954. Oak seedling ecology determining segregation of species in Piedmont oak-hickory forests. Ecological Monographs **24**:297-320.

Bourne, A. 1820. On the prairies and barrens of the West. American Journal of Science and Arts **2**:30-34.

Bowles, M. L. and J. L. McBride. 1998. Vegetation composition, structure, and chronological change in a decadent midwestern North American savanna remnant. Natural Areas Journal **18**:14-27.

Brenner, L. G., Jr. 1942. The environmental variables of the Missouri Botanical Garden Wildflower Reservation at Gray Summit. Annals of the Missouri Botanical Garden **29**:103-135.

Burns, R. M. and B. H. Honkala, technical coordinators. 1990*a*. Silvics of North America: 1. Conifers. Agriculture Handbook **654**. USDA Forest Service, Washington D.C. 675 pp.

Burns, R. M. and B. H. Honkala, technical coordinators. 1990*b*. Silvics of North America: 2. Hardwoods. Agriculture Handbook **654**. USDA Forest Service, Washington D.C. 877 pp.

Cole, K. L., P. K. Benjamin and K. F. Klick. 1990. The effects of prescribed burning on oak woods and prairies in the Indiana Dunes. Restoration and Management Notes **8**:37-38.

DeSelm, H. R. 1986. Natural forest openings on uplands of the eastern United States. Pages 366-375 *in* D. L. Kulhavy and R. N. Conner, editors. Wilderness and natural areas in the eastern United States: a management challenge. Center for Applied Studies, School of Forestry, Stephen F. Austin University, Nacogdoches, Texas.

DeSelm, H. R. 1989. The barrens of Tennessee. Journal of the Tennessee Academy of Science **64**:89-95.

DeSelm, H. R. 1994. Tennessee barrens. Castanea **59**:214-225.

DeSelm, H. R., E. E. C. Clebsch, G. M. Nichols, and E. Thor. 1974. Response of herbs, shrubs and tree sprouts in prescribed-burn hardwoods in Tennessee. Tall Timbers Fire Ecology Conference **13**:331-344.

DeSelm, H. R. and N. Murdock. 1993. Grass-dominated communities. Pages 87-141 *in* W. H. Martin, S. G. Boyce and A. C. Echternacht, editors. Biodiversity of the southeastern United States: upland terrestrial communities. John Wiley & Sons, Inc., New York, New York.

Dow. No date. Cut surface application methods. Dow Chemical Company. 7 pp.

Edgin, B. R. and J. E. Ebinger. 1997. Barrens and the forest-prairie interface in presettlement Crawford County, Illinois. Castanea **62**:260-267.

Elsenheimer, T. E. 1994. The effect of 14 years of biennial spring burning on above ground biomass and woody plant invasion in four Alexander County, Illinois hill prairies. M. S. Thesis, Southern Illinois University Carbondale, Carbondale, Illinois.

Engelmann, H. 1863. Remarks upon the causes producing the different characteristics of vegetation known as prairies, flats, and barrens in southern Illinois, with reference to observations made in Perry and Jackson counties. American Journal of Sciences and Arts **86**:384-396.

Erickson, R. O., L. G. Brenner and J. Wraight. 1942. Dolomitic glades of east-central Missouri. Annals of the Missouri Botanical Garden **29**:89-101.

Evers, R. A. and L. M. Page. 1977. Some unusual natural areas in Illinois. Biological Notes **100**, Illinois Natural History Survey, Urbana, Illinois. 47 pp.

Gehring, J. L. and T. B. Bragg. 1992. Changes in prairie vegetation under eastern red cedar (*Juniperus virginiana* L.) in an eastern Nebraska bluestem prairie. American Midland Naturalist **128**:209-217.

Guyette, R. P. and B. E. Cutter. 1991. Tree-ring analysis of fire history of a post oak savanna in the Missouri Ozarks. Natural Areas Journal **11**:93-99.

Guyette, R. and E. A. McGinnes, Jr. 1982. Fire History of an Ozark glade in Missouri. Transactions of the Missouri Academy of Science **16**:85-93.

Heikens, A. A. 1991. Classification of the natural forest openings in southern Illinois. Ph.D. Dissertation, Southern Illinois University Carbondale, Carbondale, Illinois.

Heikens, A. L. 1998. Savanna, barrens, and glade communities of the Ozark Plateau Province. Pages 220-229 *in* R. C. Anderson, J. S. Fralish and J. M. Baskin, editors. Savannas, barrens and rock outcrop plant communities of North America. Cambridge University Press, USA. In press.

Heikens, A. L. and P. A. Robertson. 1994. Barrens of the Midwest: a review of the literature. Castanea **59**:274-285.

Heikens, A. L., K. A. West and P. A. Robertson. 1994. Short-term response of chert and shale barrens vegetation to fire in southwestern Illinois. Castanea **59**:274-285.

Henderson, R. A., D. L. Lovell and E. A. Howell. 1983. The flowering response of 7 grasses to seasonal timing of prescribed burns in remnant Wisconsin prairie. Pages 7-10 *in* R. Brewer, editor. Proceedings of the eighth North American prairie conference. Western Michigan University, Kalamazoo, Michigan.

Herkert, J. R., editor. 1991. Endangered and threatened species of Illinois: status and distribution, volume 1 - plants. Illinois Endangered Species Protection Board, Springfield, Illinois. 158 pp.

Herkert, J. R., editor. 1992. Endangered and threatened species of Illinois: status and distribution, volume 2 - animals. Illinois Endangered Species Protection Board, Springfield, Illinois. 142 pp.

Hill, M. O. and H. G. Gauch, Jr. 1980. Detrended correspondence analysis: an improved ordination technique. Vegetatio **42**:47-58.

Holtz, S. L. and E. A. Howell. 1983. Restoration of grassland in a degraded woods using the management techniques of cutting and burning. Pages 124-129 *in* R. Brewer, editor. Proceedings of the eighth North American prairie conference. Western Michigan University, Kalamazoo, Michigan.

Homoya, M. A. 1994. Indiana barrens: classification and description. Castanea **59**:204-213.

Hutchison, M. D. 1992. Vegetation management guideline: smooth sumac (*Rhus glabra* L.). Natural Areas Journal **12**:158.

Hutchison, M. D., S. Olson and T. Vogt. 1986. A survey of the barrens region in Massac and Pope counties, Illinois. Natural Land Institute, Belknap, Illinois. 90 pp.

IDNR. No date. Fults Hill Prairie Nature Preserve, Kidd Lake Marsh Natural Area, Monroe County, Illinois. Site interpretation pamphlet, Illinois Department of Natural Resources, Division of Natural Heritage, Springfield, Illinois. 4 pp.

IESPB. 1994. Checklist of endangered and threatened animals and plants of Illinois. Illinois Endangered Species Protection Board, Springfield, Illinois. 20 pp.

INAI. No date. Illinois Natural Areas Inventory computer printout for Fults Hill Prairie-Kidd Lake Marsh area. Unpublished data. 7 pp.

INPC. 1971. Illinois nature preserves two-year report 1969-1970. Illinois Nature Preserves Commission, Rockford, Illinois. 49 pp.

INPC. 1990*a*. Management guidelines for Illinois nature preserves: herbicide use and application. Vol. 4., Illinois Nature Preserves Commission, Springfield, Illinois. 8 pp.

INPC. 1990*b*. Management guidelines for Illinois nature preserves: vegetation management. Vol. 1, no. 1. 5 pp.

INPC. 1990*c*. Vegetation management guidelines for Illinois nature preserves. Vol. 1, nos. 2-29, Illinois Nature Preserves Commission, Springfield, Illinois. Unpublished data.

Johnson, R. G. and R. C. Anderson. 1986. The seed bank of a tallgrass prairie in Illinois. American Midland Naturalist **115**:123-130.

Kays, J. S. and C. D. Canham. 1991. Effects of time and frequency of cutting on hardwood root reserves and sprout growth. Forest Science **37**:524-539.

Kilburn, P. D. and D. K. Warren. 1963. Vegetation-soil relationships in hill prairies. Transactions of the Illinois State Academy of Science **56**:142-145.

Kimmel, V. L. and G. E. Probasco. 1980. Change in woody cover on limestone glades between 1938 and 1975. Transactions of the Missouri Academy of Science **14**:69-74.

King, J. E. 1981. Late Quaternary vegetational history of Illinois. Ecological Monographs **51**:43-62.

Kline, V. M. and T. McClintock. 1993. Effect of burning on a dry oak forest infested with woody exotics. Pages 207-213 *in* R. G. Wickett, P. D. Lewis, A. Woodliffe, and P. Pratt, editors. Proceedings of the thirteenth North American prairie conference. Department of Parks and Recreation, Windsor, Ontario, Canada.

Kline, V. M. and T. McClintock. 1994. Changes in dry oak forest after a third prescribed burn. Pages 279-284 *in* J. S. Fralish, R. C. Anderson, J. E. Ebinger, and R. Szafoni, editors. Proceedings of the North American conference on barrens and savannas. The Environmental Protection Agency, Great Lakes National Program Office.

Kurz, D. R. 1981. Flora of limestone glades in Illinois. Pages 183-186 *in* R. L. Stuckey and K. J. Reese, editors. Ohio Biological Survey, Biological Notes No. **15**. Proceedings of the sixth North American prairie conference. College of Biological Sciences, Ohio State University, Columbus, Ohio.

Leighton, M. M., G. E. Ekblaw and L. Hornberg. 1948. Physiographic divisions of Illinois. Journal of Geology **56**:16-33.

Ley, T. W. 1994. An in-depth look at soil water monitoring and measurement tools. Irrigation Journal **44**:820.

Lorimer, C. G. 1985. The role of fire in the perpetuation of oak forests. Pages 8-25 *in* J. E. Johnson, editor. Proceedings, challenges in oak management and utilization. Cooperative Extension Service, University of Wisconsin, Madison, Wisconsin.

Ludwig, J. A. and J. F. Reynolds. 1988. Statistical ecology: a primer on methods and computing. John Wiley & Sons, New York, New York. 337 pp.

Madany, M. H. 1981. A floristic survey of savannas in Illinois. Pages 177-181 *in* R. L. Stuckey and K. J. Reese, editors. Ohio Biological Survey, Biological Notes No. **15**. Proceedings of the sixth North American prairie conference. College of Biological Sciences, Ohio State University, Columbus, Ohio.

Maxwell, R. H. 1987. Natural area remnants within the Indiana Army Ammunition Plant, Charlestown, Indiana: the little bluestem glades. Indiana Academy of Science **96**:413-419.

McCall, R. K. 1995. Microclimatic influence on spatial heterogeneity and photosynthesis in *Sorghastrum nutans* (L.) Nash. and *Helianthus divaricatus* L. on southern Illinois loess hill prairies. M. S. Thesis, Southern Illinois University at Carbondale, Carbondale, Illinois.

McCall, R. K., D. J. Gibson and K. A. West. 1998. The regeneration potential of a threatened southern Illinois shale barren. Unpublished data.

McClain, W. E. and R. C. Anderson. 1990. Loss of hill prairie through woody plant invasion at Pere Marquette State Park, Jersey County, Illinois. Natural Areas Journal **10**:69-75.

McClain, W. E., M. A. Jenkins, S. E. Jenkins, and J. E. Ebinger. 1993. Changes in the woody vegetation of a bur oak savanna remnant in central Illinois. Natural Areas Journal **13**:108-114.

McCune, B. and M. J. Mefford. 1997. PC-ORD: Multivariate analysis of ecological data, version 3.0. MjM Software Design, Gleneden Beach, Oregon. 47 pp.

McFall, D., editor. 1991. A directory of Illinois nature preserves. Illinois Department of Conservation, Division of Natural Heritage, Springfield, Illinois. 382 pp.

McInteer, B. B. 1946. A change from grassland to forest vegetation in the "Big Barrens" of Kentucky. American Midland Naturalist **35**:276-282.

Mohlenbrock, R. H. 1986. Guide to the vascular flora of Illinois. Southern Illinois University Press, Carbondale, Illinois. 507 pp.

Neiring, W. A., R. H. Goodwin and S. Taylor. 1970. Prescribed burning in southern New England: introduction to long-range studies. Tall Timbers Fire Ecology Conference **10**:267-286.

Nelson, P. W. 1987. The terrestrial natural communities of Missouri. Missouri Natural Areas Committee, Jefferson City, Missouri. 197 pp.

Nelson, P. and D. Ladd. 1983. Preliminary report on the identification, distribution and classification of Missouri glades. Pages 59-76 *in* C. L. Kucera, editor. Proceedings of the seventh North American prairie conference.

Nuzzo, V. A. and E. A. Howell. 1990. Natural area restoration planning. Natural Areas Journal **10**:201-209.

Nuzzo, V. A., W. McClain and T. Strole. 1996. Fire impact on groundlayer flora in a sand forest 1990-1994. American Midland Naturalist **136**:207-221.

Nÿboer, R. 1981. Grazing as a factor in the decline of Illinois hill prairies. Pages 209-211 *in* R.

L. Stuckey and K. J. Reese, editors. Ohio Biological Survey, Biological Notes No. **15**. Proceedings of the sixth North American prairie conference. College of Biological Sciences, Ohio State University, Columbus, Ohio.

Oksanen, J. and P. R. Minchin. 1997. Instability of ordination results under changes in input data order: explanations and remedies. Journal of Vegetation Science **8**:447-454.

Ozment, J. E. 1967. The vegetation of limestone ledges of southern Illinois. Transactions of the Illinois State Academy of Science **60**:135-173.

Pemble, R. H., G. L. Van Amburg and Lyle Mattson. 1981. Intraspecific variation in flowering activity following a spring burn on a northwestern Minnesota prairie. Pages 235-240 *in* R. L. Stuckey and K. J. Reese, editors. Ohio Biological Survey, Biological Notes No. **15**. Proceedings of the sixth North American prairie conference. College of Biological Sciences, Ohio State University, Columbus, Ohio.

Piskin, K. and R. E. Bergstrom. 1967. Glacial drift in Illinois: thickness and character. Circular **416**, Illinois State Geological Survey, Urbana, Illinois. 33 pp.

Quarterman, E. 1950. Major plant communities of Tennessee cedar glades. Ecology **31**:234-254.

Quarterman, E. 1989. Structure and dynamics of limestone cedar glade communities in Tennessee. Journal of the Tennessee Academy of Science **64**:155-158.

Quarterman, E., M. P. Burbanck and D. J. Shure. 1993. Rock outcrop communities: limestone, sandstone, and granite. Pages 35-86 *in* W. H. Martin, S. G. Boyce and A. C. Echternacht, editors. Biodiversity of the southeastern United States: upland terrestrial communities. John Wiley & Sons, Inc., New York, New York.

Robertson, P. A. and A. L. Heikens. 1994. Fire frequency in oak-hickory forests of southern Illinois. Castanea **59**:286-291.

Ross, M. S., T. L. Sharik and D. W. Smith. 1986. Oak regeneration after clear felling in southwest Virginia. Forest Science **32**:157-169.

Schwegman, J. E. 1969. Fults Hill Prairie Natural Area acquisition project proposal, Monroe County, Illinois. Unpublished report to the Illinois Nature Preserves Commission. 8 pp.

Schwegman, J. E. 1973. Comprehensive plan for the Illinois nature preserves system, part II: natural divisions of Illinois. Illinois Nature Preserves Commission, Rockford, Illinois. 32 pp.

Schwegman, J. E. 1988. Suggestions for the use of herbicides in natural areas. Natural Areas Journal **8**:277-278.

Schwegman, J. E. and R. C. Anderson. 1986. Effect of eleven years of fire exclusion on the vegetation of a southern Illinois barren remnant. Pages 146-148 *in* G. K. Clambey and R. H. Pemble, editors. Proceedings of the ninth North American prairie conference. Tri-College University Center for Environmental Studies, Moorhead, Minnesota.

Smeins, F. E. 1985. Grasslands and savannas: ecology, preservation status and management. Page 338 *in* D. L. Kulhavy and R. N. Connor, editors. Wilderness and natural areas in the eastern United States: a management challenge. Center for Applied Studies, School of Forestry, Stephen F. Austin State University, Nacogdoches, Texas.

Smith, S. D. and J. Stubbendieck. 1990. Production of tall-grass herbs below eastern redcedar. Prairie Naturalist **22**:13-18.

Steyermark, J. A. 1940. Studies of the vegetation of Missouri - I. Natural plant associations and succession in the Ozarks of Missouri. Publication **485**, Chicago Field Museum of Natural History Botanical Series **9**:349-475.

Steyermark, J. A. 1981. Flora of Missouri. Iowa State University Press, Ames, Iowa. 1728 pp.

Stritch, L. R. 1987. Barrens restoration in the Cretaceous Hills of Pope and Massac counties, Illinois. Illinois Department of Conservation, Division of Natural Heritage, Springfield, Illinois. Unpublished data. 13 pp.

Stritch, L. R. 1990*a*. Barrens restoration in the Cretaceous Hills of Pope and Massac counties, Illinois. Pages 31-37 *in* J. J. Berger, editor. Science and strategies for restoring the earth. Island Press, Washington, D.C. 398 pp.

Stritch, L. R. 1990*b*. Landscape-scale restoration of barrens-woodland within the oak-hickory forest mosaic. Restoration & Management Notes **8**:73-77.

Swan, F. R., Jr. 1970. Post-fire response of four plant communities in south-central New York state. Ecology **51**:1074-1082.

Terletzsky, P. A. and O. W. Van Auken. 1996. Comparison of cedar glades and associated woodlands of the southern Edwards Plateau. Texas Journal of Science **48**:55-67.

Tester, J. R. 1989. Effects of fire frequency on oak savanna in east-central Minnesota. Bulletin of the Torrey Botanical Club **116**:134-144.

Thom, R. 1993. The eastern red cedar. Missouri Conservationist **54**:12-19.

Thor, E. and G. M. Nichols. 1974. Some effects of fires on litter, soil, and hardwood regeneration. Tall Timbers Fire Ecology Conference **13**:317-330.

Tyndall, R. W. 1992. Historical considerations of conifer expansion in Maryland serpentine "barrens". Castanea **57**:123-131.

Tyndall, R. W. 1994. Conifer clearing and prescribed burning effects to herbaceous layer vegetation on a Maryland serpentine "barren". Castanea **59**:255-273.

USDA. 1984. Soils of Illinois. Bulletin **778**, University of Illinois at Urbana-Champaign College of Agriculture, Agricultural Experiment Station in cooperation with the USDA Soil Conservation Service, Washington, D.C. 85 pp. + 1 map.

USDA. 1987. Soil survey of Monroe County, Illinois. Illinois Agricultural Experiment Station Soil Report No. **126**, USDA Soil Conservation Service, Washington, D.C. 174 pp. + maps.

Vestal, A. G. 1936. Barrens vegetation in Illinois. Transactions of the Illinois State Academy of Science **29**:79-80.

Ward, J. S. 1992. Response of woody regeneration to thinning mature upland oak stands in Connecticut, USA. Forest Ecology and Management **49**:219-231.

Weller, S. and J. M. Weller. 1939. Preliminary geological maps of the pre-Pennsylvanian formations in part of southwestern Illinois. Report of Investigations No. **59**, State of Illinois, Division of the State Geological Survey, Urbana, Illinois. 15 pp.

White, A. S. 1983. The effect of thirteen years of annual burning on a *Quercus ellipsoidalis* community in Minnesota. Ecology **64**:1081-1085.

White, J. 1978. Illinois natural areas inventory technical report. Volume I: survey methods and results. Illinois Natural Areas Inventory, Urbana, Illinois. 426 pp.

White, J. and K. Kerr. 1980. Evaluation of Fults Hill Prairie Nature Preserve, Monroe County, Illinois as a potential national natural landmark. Report to the Division of Natural Landmarks, United States Department of the Interior. Natural Quality Services. 29 pp.

White, J. and M. H. Madany. 1978. Classification of natural communities in Illinois. Pages 309-405 *in* Illinois natural areas inventory technical report. Volume I: survey methods and results. Illinois Natural Areas Inventory, Urbana, Illinois.

Willman, H. B. and J. C. Frye. 1970. Pleistocene stratigraphy of Illinois. Bulletin **94**, Illinois State Geological Survey, Urbana, Illinois. 204 pp.

APPENDICES

Appendix 1. Plot center location data. Each plot center was mapped, using the distance in meters and the direction in degrees from the center marker to the outer edge of each of three trees, to aid in relocation of plots. Diameters in bold (JUVI, FRAM and ACSA) were measured at ground level (dgl), while all other species were measured at breast height (dbh). Abbreviations are defined in Appendices 3 and 4. * = data not collected. Comments are given to aid in location of trees.

Plot	Direction (°)	Distance (m)	Species	dbh/**dgl** (cm)	Comments
1	120	2.78	JUVI	**11.3**	
1	196	3.85	JUVI	**26.6**	
1	352	3.55	JUVI	**13.4**	
2	23	2.20	JUVI	**11.6**	
2	74	4.03	JUVI	**47.2**	
2	257	6.00	JUVI	**20.6**	
3	84	6.50	JUVI	**8.8**	
3	160	3.47	JUVI	**16.4**	
3	319	2.92	JUVI	**16.7**	
4	15	2.60	QUST	22.5	2nd stem 18.9 cm dbh
4	52	1.80	JUVI	**15.5**	
4	192	2.02	JUVI	**15.8**	
5	120	0.65	JUVI	**6.6**	
5	246	5.60	JUVI	**21.5**	
5	345	2.14	JUVI	**8.5**	
6	156	4.70	JUVI	**17.9**	
6	208	5.27	JUVI	**13.0**	
6	330	3.57	JUVI	**12.2**	
7	30	6.70	JUVI	**17.0**	
7	97	4.87	JUVI	**18.8**	
7	310	5.35	QUPR	11.1	2nd stem 10.5 cm dbh
8	98	3.96	JUVI	**9.9**	
8	131	2.89	JUVI	**37.0**	
8	220	3.05	JUVI	**25.9**	
9	89	5.67	QUVE	10.5	same tree as plot 10
9	154	3.33	QUVE	21.7	
9	270	4.78	JUVI	**12.2**	
10	60	3.47	QUPR	33.0	fire scarred
10	104	3.62	JUVI	**40.4**	
10	250	5.54	QUVE	10.5	same tree as plot 9
11	61	2.45	QUPR	43.9	stem forked
11	150	2.01	QUPR	27.7	fire scarred, w/ CARA vine
11	352	4.15	JUVI	**11.5**	
12	66	2.27	QURU	11.0	

Appendix 1 (cont.).

Plot	Direction (°)	Distance (m)	Species	dbh/**dgl** (cm)	Comments
12	150	1.25	QURU	12.4	
12	260	0.48	QURU	14.0	
13	35	1.34	QUPR	24.1	fire scarred, short trunk
13	120	2.00	QUPR	44.6	
13	294	1.20	QUPR	48.2	fire scarred
14	39	4.65	QUPR	15.4	2nd stem 22.2 cm dbh
14	110	1.41	JUVI	**36.6**	fire scarred, leaning
14	316	4.86	QUST	35.4	fire scarred
15	62	2.94	QURU	20.8	5 stemmed, 2 alive, 3 dead
15	132	4.52	QUPR	14.8	2nd stem 15.9 cm dbh
15	257	3.85	JUVI	**39.0**	1/3rd of trunk w/o bark
16	62	3.22	QUPR	16.2	2nd stem 9.3 cm dbh
16	104	5.35	JUVI	**14.4**	
16	285	2.46	QUPR	13.2	
17	70	3.27	QUPR	11.4	3 stemmed, 12.3, 9.8
17	256	4.25	QUPR	28.6	fire scarred, leaning
17	334	1.20	QURU	16.8	
18	36	1.00	QUPR	12.7	2nd stem dead stump
18	115	3.27	JUVI	**23.8**	dead, leaning uphill
18	288	1.60	JUVI	**8.2**	
19	140	4.10	QUVE	46.7	
19	168	2.67	QUVE	34.7	
19	311	2.05	QUPR	8.8	
20	111	0.34	QURU	18.4	
20	275	3.70	QUPR	19.1	2nd stem 9.1 cm dbh
20	352	1.60	QURU	12.1	
21	67	6.65	QUPR	53.7	same tree as plot 22
21	*	*	QUPR	25.2	3 stemmed, 10.3, 14.5
21	223	1.38	QUST	11.8	
22	4	4.75	QUVE	27.3	2nd stem 8.9 cm dbh
22	108	1.78	QUPR	23.9	
22	272	6.20	QUPR	53.7	same tree as plot 21
23	120	3.65	QUPR	22.8	barbed wire
23	275	5.01	JUVI	**28.7**	
23	355	2.66	QUPR	37.5	barbed wire, stem forked
24	33	3.37	QUPR	32.0	
24	189	2.12	JUVI	**39.8**	

Appendix 1 (cont.).

Plot	Direction (°)	Distance (m)	Species	dbh/dgl (cm)	Comments
24	321	3.03	QUPR	26.1	
25	67	1.75	JUVI	**8.8**	
25	132	5.20	QUPR	13.1	
25	293	0.70	JUVI	**6.7**	
26	91	4.60	JUVI	**25.8**	3 stemmed, measured to split
26	168	2.70	JUVI	**31.9**	2 stemmed, measured to split
26	332	5.65	FRAM	**43.7**	2 stemmed
27	70	6.65	JUVI	**16.2**	same tree as plot 28
27	107	3.25	JUVI	**15.1**	
27	320	4.85	JUVI	**18.2**	
28	91	3.30	JUVI	**9.0**	
28	160	2.70	JUVI	**8.5**	
28	277	5.14	JUVI	**16.2**	
29	16	0.94	JUVI	**6.8**	
29	109	6.42	JUVI	**19.5**	
29	243	2.37	JUVI	**13.0**	
30	146	5.43	JUVI	**28.5**	
30	231	2.33	JUVI	**9.0**	
30	285	5.50	JUVI	**14.7**	
31	35	4.40	JUVI	**31.4**	
31	80	0.63	JUVI	**8.3**	
31	190	2.87	FRAM	**25.2**	2 stemmed
32	81	4.20	JUVI	**15.4**	
32	192	3.17	JUVI	**13.3**	
32	276	3.50	JUVI	**19.0**	
33	50	3.75	QUPR	23.7	
33	167	0.97	CATE	24.1	fire scarred, twisted
33	256	3.90	JUVI	**32.2**	
34	41	4.60	JUVI	**35.0**	2nd stem 14.5 cm dbh
34	193	1.11	ACSA	**11.0**	7 stemmed
34	292	2.83	QURU	14.5	
35	145	1.38	CATE	25.5	
35	245	5.45	QURU	14.2	
35	321	2.26	CATE	17.1	
36	15	4.65	QUPR	12.6	2nd stem 12.2 cm dbh
36	135	1.92	QUPR	6.8	dead, 2nd stem alive, 19.0
36	227	1.93	JUVI	**34.9**	2nd stem 8.7 cm dbh

Appendix 1 (cont.).

Plot	Direction (°)	Distance (m)	Species	dbh/dgl (cm)	Comments
37	140	4.90	JUVI	*	
37	182	46.1	QURU	12.4	
37	320	1.90	QUPR	31.5	3 stemmed, 27.5, 37.5
38	107	3.27	QUVE	9.7	
38	257	4.14	QUPR	8.7	
38	298	2.85	JUVI	**7.9**	
39	46	6.00	FRAM	**11.5**	3 stemmed, 8.4, 12.6
39	112	5.13	ACSA	**31.9**	
39	262	3.65	QUPR	14.3	2nd stem 25.3 cm dbh
40	42	2.16	QUVE	13.8	
40	142	5.43	QURU	31.5	
40	339	3.40	JUVI	**39.4**	dead, fire scarred
41	23	0.60	JUVI	**25.6**	stump, w/ TORA vine
41	141	1.68	QUPR	14.8	2 stems, measured to split
41	303	0.90	QUPR	14.1	
42	23	5.50	QUPR	13.0	alive, 2nd stem dead, 5.3
42	101	4.10	QUPR	17.7	
42	310	5.40	QURU	20.8	
43	69	5.55	QUPR	27.6	
43	164	4.41	QUPR	17.8	2nd stem 16.0 cm dbh
43	320	3.41	QURU	11.9	
44	99	4.60	QURU	24.1	
44	213	3.80	QUPR	25.4	bulge at base
44	263	5.70	QUPR	27.8	
45	47	3.40	JUVI	**17.5**	
45	170	4.40	QURU	40.3	
45	275	2.80	QUPR	18.6	2nd stem 19.4 cm dbh
46	32	4.05	QUPR	24.1	
46	141	7.35	JUVI	**29.1**	dead, broken snag
46	299	2.02	QUPR	35.4	
47	40	3.80	JUVI	**33.3**	w/ large TORA vine
47	168	3.78	QUPR	28.2	
47	287	1.61	QUPR	32.6	
48	67	3.27	QUPR	37.4	
48	277	0.50	QUPR	12.2	dead
48	321	1.85	QUPR	28.1	

Appendix 2. Location of 1 m^2 plots within 0.01 ha plots. C = close (2 - 3 m) and F = far (3 - 4 m), indicationg the proximity of 1 m^2 plots to 0.01 ha plot center. Plots were numbered 1 - 8 clockwise. See Figure 3 for diagram of plot layout.

Plot	1 m^2 plots	Plot	1 m^2 plots
1	1f, 2c, 4c, 6f, 7c, 8c	25	1f, 2f, 3c, 5c, 7c, 8c
2	1f, 2c, 3f, 5c, 7c, 8c	26	2c, 3f, 4f, 6c, 7f, 8f
3	1f, 2f, 3c, 4c, 7c, 8c	27	1c, 3f, 4c, 6c, 7f, 8f
4	1c, 3c, 4f, 5c, 6c, 8f	28	1c, 2c, 3f, 4f, 6c, 7f
5	1c, 2f, 3c, 5f, 6f, 7c	29	1c, 2f, 4c, 6c, 7f, 8f
6	1c, 2c, 3f, 4c, 6c, 8f	30	1f, 3c, 4f, 5c, 6f, 8c
7	2c, 3f, 4c, 5f, 6f, 8c	31	2f, 3c, 4c, 6f, 7c, 8c
8	1c, 2f, 4c, 6c, 7f, 8f	32	1c, 2f, 3c, 4f, 5c, 7c
9	1f, 3f, 4f, 6f, 7c, 8c	33	1c, 2f, 3c, 5f, 7f, 8f
10	1c, 2f, 3c, 5c, 6c, 8f	34	2c, 4c, 5f, 6f, 7c, 8c
11	1c, 2c, 4c, 6f, 7c, 8f	35	2c, 3f, 4f, 6f, 7c, 8c
12	1f, 2f, 3c, 4f, 5c, 7f	36	1c, 3f, 4f, 5c, 7c, 8f
13	1c, 2c, 3f, 5f, 6c, 8f	37	1f, 2c, 4f, 6c, 7f, 8c
14	1c, 2f, 3c, 6f, 7c, 8f	38	1c, 2c, 3f, 4c, 6c, 8f
15	1c, 2c, 4f, 5c, 6f, 8f	39	1c, 2c, 3f, 4f, 6c, 7f
16	2c, 3f, 4f, 5c, 6c, 8c	40	1f, 2f, 3c, 4f, 6f, 8c
17	1f, 2f, 3c, 5c, 6c, 7f	41	1c, 2f, 4c, 6f, 7c, 8f
18	1c, 3c, 4f, 5c, 6f, 7c	42	1f, 2c, 3f, 4f, 6f, 7c
19	1f, 3c, 4f, 5c, 6f, 7c	43	2c, 3f, 4c, 5f, 6c, 8c
20	2c, 3f, 4c, 5f, 6c, 8c	44	1c, 3f, 4c, 5f, 6c, 8f
21	2f, 3c, 5f, 6c, 7f, 8f	45	1c, 2f, 4f, 5c, 6f, 8f
22	1c, 2f, 3c, 5c, 7c, 8f	46	1f, 3f, 4c, 6c, 7f, 8c
23	2f, 3c, 4f, 5c, 6c, 8f	47	2f, 3c, 4c, 5f, 6c, 8c
24	1f, 2f, 3c, 5f, 7f, 8c	48	1f, 2c, 3f, 4f, 6f, 8c

Appendix 3. Barrens vegetation species list. Additional species are ephemerals or species found within the community, but not sampled in plots.

Species	Abbreviation	Species	Abbreviation
Herbaceous (92)			
Acalypha gracilens	ACAGRA	*Eupatorium perfoliatum*	EUPPER
Agalinis tenuifolia	AGATEN	*Eupatorium rugosum*	EUPRUG
Agrimonia pubescens	AGRPUB	*Euphorbia corollata*	EUPCOR
Agrimonia rostellata	AGRROS	*Festuca obtusa*	FESOBT
Amphicarpa bracteata	AMPBRA	*Galactia regularis*	GALREG
Anemone virginiana	ANEVIR	*Galium circaezans*	GALCIR
Antennaria plantaginifolia	ANTPLA	*Galium pilosum*	GALPIL
Aristolochia serpentaria	ARISER	*Galium triflorum*	GALTRI
Asplenium platyneuron	ASPPLA	*Geum candense*	GEUCAN
Aster anomalous	ASTANO	*Glandularia canadensis*	GLACAN
Aster patens	ASTPAT	*Hedyotis nuttalliana*	HEDNUT
Aster turbinellus	ASTTUR	*Helianthus divaricatus*	HELDIV
Botrychium virginianum	BOTVIR	*Ipomoea pandurata*	IPOPAN
Bouteloua curtipendula	BOUCUR	*Lactuca canadensis*	LACCAN
Bromus pubescens	BROPUB	*Lactuca floridana*	LACFLO
Carex blanda	CARBLA	*Lactuca serriola*	LACSER
Carex spp.	CARSPP	*Lespedeza procumbens*	LESPRO
Cassia fasciculata	CASFAS	*Lespedeza* spp.	LESSPP
Ceanothus americanus	CEAAME	*Lespedeza virginica*	LESVIR
Chamaesyce maculata	CHAMAC	*Leucospora multifida*	LEUMUL
Chenopodium albidum	CHEALB	*Lithospermum canescens*	LITCAN
Cirsium altissimum	CIRALT	*Monarda bradburiana*	MONBRA
Cocculus carolinus	COCCAR	*Muhlenbergia sobolifera*	MUHSOB
Conyza canadensis	CONCAN	*Oxalis dillenii*	OXADIL
Croton glandulosus	CROGLA	*Panicum flexile*	PANFLE
Croton monanthogynus	CROMON	*Passiflora lutea*	PASLUT
Cunila origanoides	CUNORI	*Pellaea atropurpurea*	PELATR
Desmodium glabellum	DESGLA	*Penstemon pallidus*	PENPAL
Desmodium glutinosum	DESGLU	*Phryma leptostachya*	PHRLEP
Desmodium nudiflorum	DESNUD	*Physalis heterophylla*	PHYHET
Desmodium paniculatum	DESPAN	*Physostegia virginiana*	PHYVIR
Dichanthelium acuminatum	DICACU	*Phytolacca americana*	PHYAME
Dichanthelium boscii	DICBOS	*Poinsettia dentata*	POIDEN
Dioscorea quaternata	DIOQUA	*Pycnanthemum pilosum*	PYCPIL
Elymus virginicus	ELYVIR	*Ratibida pinnata*	RATPIN
Eragrostis capillaris	ERACAP	*Ruellia humilis*	RUEHUM
Erechtites hieracifolia	EREHIE	*Sanicula canadensis*	SANCAN
Erigeron annuus	ERIANN	*Schizachyrium scoparium*	SCHSCO

Appendix 3 (cont.).

Species	Abbreviation	Species	Abbreviation
Senecio plattensis	SENPLA	*Tridens flavus*	TRIFLA
Setaria viridis	SETVIR	*Triosteum aurantiacum*	TRIAUR
Solanum ptycanthum	SOLPTY	*Verbascum thapsis*	VERTHA
Solidago gigantea	SOLGIG	*Verbesina helianthoides*	VERHEL
Solidago petiolaris	SOLPET	*Viola pratincola*	VIOPRA
Solidago radula	SOLRAD	*Viola sororia*	VIOSOR
Solidago ulmifolia	SOLULM	*Viola triloba*	VIOTRI
Sorghastum nutans	SORNUT	*Woodsia obtusa*	WOOOBT
Woody (45)			
Acer rubrum	ACRU	*Juglans nigra*	JUNI
Acer saccharum	ACSA	*Juniperus virginiana*	JUVI
Amelanchier arborea	AMAR	*Morus rubra*	MORU
Asimina triloba	ASTR	*Parthenocissus quinquefolia*	PAQU
Bumelia lanuginosa[c]	BULA	*Prunus serotina*	PRSE
Campsis radicans	CARA	*Quercus alba*	QUAL
Carya cordiformis	CACO	*Quercus marilandica*	QUMA
Carya glabra	CAGL	*Quercus prinoides*	QUPR
Carya ovalis	CAOVL	*Quercus rubra*	QURU
Carya ovata	CAOVT	*Quercus stellata*	QUST
Carya texana	CATE	*Quercus velutina*	QUVE
Celastrus scandens	CESC	*Rhamnus caroliniana*	RHCA
Celtis occidentalis	CEOC	*Rhus aromatica*	RHAR
Cercis canadensis	CECA	*Rhus copallina*	RHCO
Cornus drummondii	CODR	*Rhus glabra*	RHGL
Cornus florida	COFL	*Rosa carolina*	ROSCAR
Diospyros virginiana	DIVI	*Rosa multiflora*	ROSMUL
Fraxinus americana	FRAM	*Rubus enslenii*	RUBENS
Fraxinus quadrangulata	FRQU	*Sassafras albidum*	SAAL
Ilex decidua	ILDE	*Smilax hispida*	SMIHIS
Symphoricarpos orbiculatus	SYMORB	*Viburnum rufidulum*	VIRU
Toxicodendron radicans	TORA	*Vitis cinerea*	VICI
Ulmus rubra	ULRU		
Additional (22)			
Arabis canadensis		*Cirsium vulgare*	
Asparagus officinalis		*Claytonia virginica*	
Aster pilosus		*Danthonia spicata*	
Bidens bipinnata		*Daucus carota*	
Campanula americana		*Descuriana pinnata*	

Appendix 3 (cont.).

Species	Abbreviation	Species	Abbreviation
Echinacea simulata		*Oxalis violacea*	
Elymus histrix		*Ranunculus micranthus*	
Erigeron philadelphicus		*Rudbeckia hirta*	
Erigeron pulchellus		*Smilax bona-nox*	
Muhlenbergia frondosa		*Sphenopholis obtusata*	
Orobanche uniflora		*Vernonia baldwinii*	
Total number of species = 159			

[e] Endangered in Illinois.

Appendix 4. Glade vegetation species list. Additional species are ephemerals or species found within the community, but not sampled in plots.

Species	Abbreviation	Species	Abbreviation
Herbaceous (80)			
Acalypha gracilens	ACAGRA	*Festuca obtusa*	FESOBT
Agalinis tenuifolia	AGATEN	*Galactia regularis*	GALREG
Agrimonia pubescens	AGRPUB	*Galium circaezans*	GALCIR
Agrimonia rostellata	AGRROS	*Galium pilosum*	GALPIL
Agrostis perennans	AGRPER	*Geum candense*	GEUCAN
Allium stellatum	ALLSTE	*Glandularia canadensis*	GLACAN
Amphicarpa bracteata	AMPBRA	*Helianthus divaricatus*	HELDIV
Anemone virginiana	ANEVIR	*Lactuca canadensis*	LACCAN
Aristida longespica	ARILON	*Lespedeza capitata*	LESCAP
Asclepias verticillata	ASCVER	*Lespedeza virginica*	LESVIR
Ascelepias viridiflora	ASCVIR	*Leucospora multifida*	LEUMUL
Asplenium platyneuron	ASPPLA	*Manfreda virginica*	MANVIR
Aster anomalous	ASTANO	*Monarda bradburiana*	MONBRA
Aster oblongifolius	ASTOBL	*Muhlenbergia sobolifera*	MUHSOB
Aster patens	ASTPAT	*Opuntia humifusa*	OPUHUM
Bouteloua curtipendula	BOUCUR	*Oxalis dillenii*	OXADIL
Brickellia eupatorioides	BRIEUP	*Panicum flexile*	PANFLE
Bromus commutatus	BROCOM	*Passiflora lutea*	PASLUT
Bromus pubescens	BROPUB	*Pellaea atropurpurea*	PELATR
Carex spp.	CARSPP	*Penstemon pallidus*	PENPAL
Cassia fasciculata	CASFAS	*Phryma leptostachya*	PHRLEP
Chamaesyce maculata	CHAMAC	*Poa pratensis*	POAPRA
Chenopodium albidum	CHEALB	*Poa* sp.	POASP.
Croton monanthogynus	CROMON	*Poinsettia dentata*	POIDEN
Cunila origanoides	CUNORI	*Polygonum tenue*	POLTEN
Dalea candida	DALCAN	*Ratibida pinnata*	RATPIN
Desmodium glabellum	DESGLA	*Rudbeckia missouriensis*[e]	RUDMIS
Desmodium glutinosum	DESGLU	*Ruellia humilis*	RUEHUM
Desmodium paniculatum	DESPAN	*Sanicula canadensis*	SANCAN
Dichanthelium acuminatum	DICACU	*Schizachyrium scoparium*	SCHSCO
Dichanthelium boscii	DICBOS	*Senecio plattensis*	SENPLA
Digitaria ischaemum	DIGISC	*Setaria faberi*	SETFAB
Elymus virginicus	ELYVIR	*Setaria viridis*	SETVIR
Eragrostis capillaris	ERACAP	*Sisyrinchium albidum*	SISALB
Eragrostis spectabilis	ERASPE	*Solidago radula*	SOLRAD
Erigeron annuus	ERIANN	*Solidago ulmifolia*	SOLULM
Eupatorium altissimum	EUPALT	*Sporobolus vaginiflorus*	SPOVAG
Euphorbia corollata	EUPCOR	*Stylosanthes biflora*	STYBIF

Appendix 4 (cont.).

Species	Abbreviation	Species	Abbreviation
Trichostema brachiatum	TRIBRA	*Verbascum thapsis*	VERTHA
Tridens flavus	TRIFLA	*Verbena urticifolia*	VERURT
Woody (35)			
Acer saccharum	ACSA	*Quercus alba*	QUAL
Carya glabra	CAGL	*Quercus prinoides*	QUPR
Carya ovalis	CAOVL	*Quercus rubra*	QURU
Carya ovata	CAOVT	*Quercus stellata*	QUST
Carya texana	CATE	*Quercus velutina*	QUVE
Celastrus scandens	CESC	*Rhamnus caroliniana*	RHCA
Celtis occidentalis	CEOC	*Rhus aromatica*	RHAR
Cercis canadensis	CECA	*Rhus copallina*	RHCO
Cornus drummondii	CODR	*Rhus glabra*	RHGL
Cornus florida	COFL	*Rosa carolina*	ROSCAR
Diospyros virginiana	DIVI	*Rosa multiflora*	ROSMUL
Fraxinus americana	FRAM	*Rubus enslenii*	RUBENS
Fraxinus quadrangulata	FRQU	*Smilax hispida*	SMIHIS
Juglans nigra	JUNI	*Symphoricarpos orbiculatus*	SYMORB
Juniperus virginiana	JUVI	*Toxicodendron radicans*	TORA
Parthenocissus quinquefolia	PAQU	*Ulmus rubra*	ULRU
Prunus serotina	PRSE	*Vitis cinerea*	VICI
Ptelea trifoliata	PTTR		
Additional (22)			
Allium vineale		*Myosotis macrosperma*	
Arabis canadensis		*Oxalis violacea*	
Aster pilosus		*Panicum oligosanthes*	
Bromus tectorum		*Polytaenia nuttallii*	
Draba reptans		*Psoralea tenuiflora*	
Erigeron philadelphicus		*Rubus occidentalis*	
Galium virgatum[e]		*Scutellaria australis*	
Hexalectris spicata[e]		*Sphenopholis obtusata*	
Koeleria macrantha		*Tradescantia ohiensis*	
Lithospermum incisum		*Triodanis perfoliata*	
Melica nitens		*Vulpia octoflora*	
Total number of species = 137			

[e] Endangered in Illinois.

Appendix 5. Occurrence and change in basal area for barrens tree species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 3. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, 00 = absent both years, and * = basal area present at <0.05 m^2/ha.

Species		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACSA		+-	+=	+=	+-	+-
CAGL		+=	00	+=	00	00
CATE		+-	+=	+=	+0	+-
CECA		+-	00	+-	+0	+0
COFL		+=	+*=	+=	+-*	00
FRAM		+-	+=	+-	+-	+0
JUVI		+-	+=	+-	+-*	+-
QUPR		+-	+-	+=	+-	+-
QURU		+-	+=	+=	+-	+-
QUST		+=	00	+=	+0	00
QUVE		+-	+-	+=	+-	00
RHCA		+-*	00	+*=	+*0	+0
SAAL		+*0	00	00	+0	00
TORA		+*=	+=	00	00	00
ULRU		+=	+=	+=	00	00
VICI		+*=	00	+*=	00	00
Total number of species (*S*)[a]	1994	16	10	14	12	8
	1995	15	10	14	7	5

[a] *S* varies from Table 2 *S* which includes cover species as well.

Appendix 6. Occurrence and change in density for barrens tree species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 3. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, and 00 = absent both years.

Species		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACSA		+-	+=	+=	+-	+-
CAGL		+=	00	+=	00	00
CATE		+-	+=	+=	+0	+-
CECA		+-	00	+-	+0	+0
COFL		+=	+=	+=	+-	00
FRAM		+-	+=	+-	+-	+0
JUVI		+-	+=	+-	+-	+-
QUPR		+-	+-	+=	+-	+-
QURU		+-	+=	+=	+-	+-
QUST		+=	00	+=	+0	00
QUVE		+-	+-	+=	+-	00
RHCA		+-	00	+=	+0	+0
SAAL		+0	00	00	+0	00
TORA		+=	+=	00	00	00
ULRU		+=	+=	+=	00	00
VICI		+=	00	+=	00	00
Total number of species (*S*)[a]	1994	16	10	14	12	8
	1995	15	10	14	7	5

[a] *S* varies from Table 2 *S* which includes cover species as well.

Appendix 7. Occurrence and change in cover for barrens tree species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 3. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, 00 = absent both years, and * = cover present at <0.05%.

Species		Overall n=32	CN n=8	BO n=12	CH n=8	CB n=4
ACSA		+-	++	+-	+-	+-
CAGL		+-*	00	+-*	00	00
CATE		+-	+-	+-	+0	+-
CECA		+-	+-	+-	+0	+-
COFL		+-	+-	+-	+-	00
FRAM		+-	+-	+-	+-	+0
JUVI		+-	+-	+-	+-	+-
QUAL		++	00	00	++	00
QUPR		+-	+-	+-	+-	+-
QURU		+-	+-	+-	+-	+-
QUST		+-	+0	+-	+-	00
QUVE		+-	+-	+-	+-	00
RHCA		+-	0+	+-	+0	+0
SAAL		+0	00	00	+0	00
TORA		+=	+=	00	00	00
ULRU		+-	+-	+-	00	00
Total number of species (S)[a]	1994	16	12	13	13	8
	1995	15	12	13	9	6

[a] S varies from Table 2 S which includes basal area/density species as well.

Appendix 8. Mean basal area for prominent barrens tree species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 3. * = basal area present at <0.05 m²/ha. Change associated with * values is reported to the nearest 0.1 m²/ha.

Species	Year/Change	Basal area (m²/ha)				
		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACSA	1994	1.9	1.6	1.8	2.0	2.5
		2.8	*1.6*	*2.6*	*4.1*	*3.4*
	1995	1.4	1.6	1.8	1.0	0.4
		2.2	*1.6*	*2.6*	*2.8*	*0.9*
	Change	-0.5	0.0	0.0	-1.0	-2.1
FRAM	1994	1.3	1.3	1.4	1.7	0.2
		1.7	*1.7*	*2.2*	*1.7*	*0.3*
	1995	0.7	1.3	0.9	0.1	0.0
		1.2	*1.7*	*1.2*	*0.3*	*0.0*
	Change	-0.6	0.0	-0.5	-1.6	-0.2
JUVI	1994	3.6	1.4	2.9	2.3	12.5
		5.4	*2.6*	*3.6*	*3.4*	*9.4*
	1995	1.6	1.4	2.8	*	1.2
		2.8	*2.6*	*3.5*		*2.5*
	Change	-2.0	0.0	-0.1	-2.3	-11.3
QUPR	1994	11.9	12.8	11.2	11.1	13.8
		9.2	*5.9*	*10.9*	*9.1*	*12.4*
	1995	11.1	12.7	11.2	8.7	12.5
		9.7	*5.9*	*10.9*	*10.5*	*13.3*
	Change	-0.8	-0.1	0.0	-2.4	-1.3
QURU	1994	3.4	5.3	2.6	3.8	1.2
		4.9	*6.3*	*3.7*	*6.2*	*1.1*
	1995	2.7	5.3	2.6	1.4	0.4
		4.3	*6.3*	*3.7*	*2.8*	*0.8*
	Change	-0.4	0.0	0.0	-2.4	-0.8
Total mean prominent species basal area	1994	22.1	22.4	19.9	20.9	30.2
	1995	17.5	22.3	19.3	11.2	14.5
	Change	-4.6	-0.1	-0.6	-9.7	-15.7
Total mean other species basal area	1994	3.1	4.7	2.9	1.7	3.4
	1995	2.4	3.5	2.9	0.4	3.0
	Change	-0.7	-1.2	0	-1.3	-0.4

Appendix 8 (cont.).

Species	Year/Change	Basal area (m^2/ha)				
		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
Total mean basal area	1994	25.2 *10.4*	27.1 *6.3*	22.8 *13.5*	22.6 *8.3*	33.6 *7.7*
	1995	19.9 *11.8*	25.8 *5.3*	22.2 *12.5*	11.6 *8.9*	17.5 *17.6*
	Change	-5.3	-1.3	-0.6	-11.0	-16.1
Total number of species (*S*)[a]	1994	16	10	14	12	8
	1995	15	10	14	7	5

[a] *S* varies from Table 2 *S* which includes cover species as well.

Appendix 9. Mean density for prominent barrens tree species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 3.

Species	Year/Change	Density (stem/ha)				
		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACSA	1994	231	325	208	125	325
		265	*260*	*247*	*231*	*386*
	1995	166	325	208	12	25
		231	*260*	*247*	*35*	*50*
	Change	-65	0	0	-113	-300
FRAM	1994	184	200	167	250	75
		207	*256*	*192*	*220*	*96*
	1995	119	200	158	38	0
		186	*256*	*178*	*106*	*0*
	Change	-65	0	-9	-212	-75
JUVI	1994	112	50	75	162	250
		129	*76*	*75*	*177*	*129*
	1995	41	50	58	12	25
		61	*76*	*67*	*35*	*50*
	Change	-71	0	-17	-150	-225
QUPR	1994	434	512	425	388	400
		248	*327*	*256*	*173*	*231*
	1995	353	500	425	125	300
		278	*312*	*256*	*149*	*245*
	Change	-81	-12	0	-263	-100
QURU	1994	194	250	142	262	100
		294	*293*	*227*	*441*	*82*
	1995	125	250	142	25	25
		216	*293*	*227*	*46*	*50*
	Change	-69	0	0	-237	-75
Total mean prominent species density	1994	1155	1337	1017	1187	1150
	1995	804	1325	991	212	375
	Change	-351	-12	-26	-975	-775
Total mean other species density	1994	254	263	241	276	225
	1995	165	250	234	26	75
	Change	-89	-13	-7	-250	-150

Appendix 9 (cont.).

Species	Year/Change	Density (stem/ha) Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
Total mean density	1994	1409 *475*	1600 *678*	1258 *412*	1463 *407*	1375 222
	1995	969 *697*	1575 *663*	1225 *429*	238 *226*	450 *300*
	Change	-440	-25	-33	-1225	-925
Total number of species (*S*)[a]	1994	16	10	14	12	8
	1995	15	10	14	7	5

[a] *S* varies from Table 2 *S* which includes cover species as well.

Appendix 10. Mean cover for prominent barrens tree species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 3.

Species	Year/Change	Cover (%)				
		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACSA	1994	26.2 *24.5*	32.1 *24.9*	24.9 *23.5*	22.1 *31.5*	26.2 *16.7*
	1995	19.3 *21.9*	32.8 *22.4*	23.9 *24.0*	5.1 *9.0*	7.2 *13.8*
	Change	-6.9	+0.7	-1.0	-17.0	-19.0
FRAM	1994	8.2 *7.8*	7.8 *6.3*	7.8 *8.0*	12.0 *9.2*	2.2 *3.9*
	1995	2.9 *4.5*	5.6 *5.9*	3.9 *4.5*	0.1 *0.4*	0.0 *0.0*
	Change	-5.3	-2.2	-3.9	-11.9	-2.2
JUVI	1994	9.2 *10.8*	4.2 *5.8*	6.2 *6.6*	8.9 *8.1*	29.2 *13.5*
	1995	1.7 *2.6*	1.4 *1.7*	3.2 *3.5*	0.2 *0.7*	0.8 *1.5*
	Change	-7.5	-2.8	-3.0	-8.7	-28.4
QUPR	1994	38.9 *17.0*	45.0 *14.3*	40.3 *16.0*	29.4 *16.2*	41.8 *24.3*
	1995	28.8 *16.2*	29.0 *7.0*	36.9 *14.5*	19.8 *21.4*	21.8 *14.5*
	Change	-10.1	-16.0	-3.4	-9.6	-20.0
QURU	1994	14.8 *15.9*	19.6 *19.2*	12.2 *12.5*	15.9 *20.1*	10.5 *10.8*
	1995	7.5 *10.4*	14.9 *15.3*	8.6 *8.5*	1.8 *2.7*	0.8 *1.5*
	Change	-7.3	-4.7	-3.6	-14.1	-9.7
Total mean prominent species cover	1994	97.3	108.7	91.4	88.3	109.9
	1995	60.2	83.7	76.5	27.0	30.6
	Change	-37.1	-25.0	-14.9	-61.3	-79.3
Total mean other species cover	1994	16.0	13.1	18.3	13.7	20.3
	1995	7.9	7.2	10.6	3.1	11.1
	Change	-8.1	-5.9	-7.7	-10.6	-9.2

Appendix 10 (cont.).

Species	Year/Change	Cover (%)				
		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
Total mean species cover	1994	113.3 *28.8*	121.8 *31.5*	109.7 *30.6*	102.0 *26.6*	130.2 *13.5*
	1995	68.1 *32.8*	90.9 *13.8*	87.1 *14.8*	30.1 *18.7*	41.7 *38.0*
	Change	-45.2	-30.9	-22.6	-71.9	-88.5
Total number of species (*S*)[a]	1994	16	12	13	13	8
	1995	15	12	13	9	6

[a] *S* varies from Table 2 *S* which includes basal area/density species as well.

Appendix 11. Occurrence and change in density for barrens sapling/shrub species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 3. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, and 00 = absent both years.

Species		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACSA		+-	+-	+-	+-	+-
AMAR		+-	+-	+-	+0	00
BULA[e]		+=	+=	00	00	00
CAGL		+=	+=	00	00	00
CAOVL		+0	00	00	+0	00
CAOVT		+=	00	+=	00	00
CARA		+=	00	00	+=	00
CATE		+-	+-	+-	+-	+0
CECA		+-	+-	+-	+-	+0
CEOC		+-	+-	+-	++	+0
CESC		+0	+0	00	00	00
CODR		+-	+-	+-	+-	+0
COFL		+-	+-	+-	+=	+0
DIVI		+-	+=	+0	+0	00
FRAM		+-	+-	+-	+-	+-
FRQU		+=	00	+=	00	00
ILDE		+-	+=	00	00	+0
JUVI		+-	+-	+-	+-	+0
QUPR		+-	+=	+-	+-	+-
QURU		++	+=	+-	+=	0+
QUVE		+=	00	+=	+0	00
RHAR		+-	+-	+0	+-	00
RHCA		+-	+-	+-	+-	+0
RHCO		+0	00	00	+0	00
TORA		+-	+=	+-	+-	+=
ULRU		+0	00	+0	00	+0
VICI		+-	+-	+-	+-	+0
VIRU		+-	+=	+-	+-	+-
Total number of species (*S*)	1994	28	21	21	21	15
	1995	24	20	18	16	6

[e] Endangered in Illinois.

Appendix 12. Occurrence and change in cover for barrens sapling/shrub species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 3. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, 00 = absent both years, and * = cover present at <0.05%.

Species		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACSA		+-	+-	+-	+-	+-
AMAR		+-	+-	+-*	+0	00
BULA[e]		+*=	+=	00	00	00
CAGL		+=	+=	00	00	00
CAOVL		+*0	00	00	+0	00
CAOVT		+*=	00	+-*	00	00
CARA		+*=	00	00	+=	00
CATE		+-	+=	+-	+-	+0
CECA		+-	+-	+-	+-	+0
CEOC		+-	+-	+-	+=	+0
CESC		+*0	+0	00	00	00
CODR		+-	++	+-	+-	+0
COFL		+-	+-	+-	+-	+0
DIVI		+-	+=	+*0	+0	00
FRAM		+-	+-	+-	+-	+-
FRQU		+-*	00	+-*	00	00
ILDE		+-*	+-	00	00	+0
JUVI		+-	+-	+-	+-	+0
QUPR		+-	+-	+-	+-	+-
QURU		+-	+-	+-*	+=	0+
QUVE		+-	00	+-	+0	00
RHAR		+-	+-	+0	+-	00
RHCA		+-	+-	+-	+-	+0
RHCO		+*0	00	00	+0	00
TORA		+-	+-	+-	+-	+=
ULRU		+0	00	+0	00	+0
VICI		+-	+-	+-	+-	+0
VIRU		+-	+=	+-	+-	+-
Total number of species (*S*)	1994	28	21	21	21	15
	1995	24	20	18	16	6

[e] Endangered in Illinois.

Appendix 13. Mean density for prominent barrens sapling/shrub species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 3.

Species	Year/Change	Density (stem/ha)				
		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACSA	1994	534 *665*	875 *778*	633 *768*	238 *262*	150 *238*
	1995	316 *451*	562 *560*	408 *491*	75 *89*	25 *50*
	Change	-218	-313	-225	-163	-125
CODR	1994	712 *653*	512 *749*	800 *538*	788 *844*	700 *469*
	1995	353 *475*	412 *688*	350 *318*	475 *526*	0 *0*
	Change	-359	-100	-450	-313	-700
COFL	1994	212 *195*	125 *104*	333 *239*	150 *120*	150 *173*
	1995	166 *182*	75 *116*	292 *207*	150 *120*	0 *0*
	Change	-46	-50	-41	0	-150
JUVI	1994	672 *857*	288 *473*	675 *884*	1050 *1104*	675 *763*
	1995	109 *247*	262 *431*	100 *160*	25 *46*	0 *0*
	Change	-563	-26	-575	-1025	-675
RHCA	1994	231 *194*	162 *192*	150 *117*	312 *210*	450 *173*
	1995	91 *140*	88 *99*	50 *80*	200 *214*	0 *0*
	Change	-140	-74	-100	-112	-450
VIRU	1994	197 *471*	225 *560*	75 *87*	138 *207*	625 *1060*
	1995	94 *293*	225 *560*	42 *67*	75 *175*	25 *50*
	Change	-103	0	-33	-63	-600
Total mean prominent species density	1994	2558	2187	2666	2676	2750
	1995	1129	1624	1242	1000	50
	Change	-1429	-563	-1424	-1676	-2700

Appendix 13 (cont.).

Species	Year/Change	Density (stem/ha) Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
Total mean other species density	1994	951	1188	917	886	700
	1995	524	863	425	475	250
	Change	-427	-325	-492	-411	-450
Total mean species density	1994	3509 *1599*	3375 *1339*	3583 *1160*	3562 *2244*	3450 *2339*
	1995	1653 *1206*	2487 *1589*	1667 *695*	1475 *1131*	300 *82*
	Change	-1856	-888	-1916	-2087	-3150
Total number of species (*S*)	1994	28	21	21	21	15
	1995	24	20	18	16	6

Appendix 14. Mean cover for prominent barrens sapling/shrub species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 3.

Species	Year/Change	Cover (%)				
		Overall n=32	CN n=8	BO n=12	CH n=8	CB n=4
ACSA	1994	10.0	20.0	9.3	4.5	3.2
		12.2	*15.3*	*11.6*	*5.1*	*3.9*
	1995	4.6	8.3	6.2	0.6	0.1
		7.9	*7.3*	*10.5*	*0.7*	*0.2*
	Change	-5.4	-11.7	-3.1	-3.9	-3.1
CODR	1994	6.0	3.5	5.8	6.8	10.5
		6.5	*6.8*	*4.6*	*8.0*	*7.9*
	1995	2.1	4.2	1.5	2.0	0
		5.3	*10.4*	*1.8*	*1.9*	*0*
	Change	-3.9	+0.7	-4.3	-4.8	-10.5
COFL	1994	4.0	2.9	5.9	2.8	3.2
		3.6	*2.4*	*4.4*	*2.8*	*3.3*
	1995	2.9	1.5	5.7	1.6	0
		3.8	*2.3*	*4.6*	*1.8*	*0*
	Change	-1.1	-1.4	-0.2	-1.2	-3.2
JUVI	1994	5.1	1.5	5.7	6.7	7.0
		8.1	*2.5*	*10.6*	*7.6*	*8.0*
	1995	0.3	0.8	0.3	0.1	0
		0.7	*1.1*	*0.4*	*0.2*	*0*
	Change	-4.8	-0.7	-5.4	-6.6	-7.0
RHCA	1994	3.3	2.6	1.3	3.7	10.2
		4.1	*3.2*	*1.2*	*1.8*	*7.4*
	1995	0.7	1.3	0.4	0.7	0
		1.1	*1.7*	*0.7*	*0.7*	*0*
	Change	-2.6	-1.3	-0.9	-3.0	-10.2
VIRU	1994	1.6	0.5	0.6	1.4	7.5
		4.0	*0.9*	1.1	*2.1*	*9.6*
	1995	0.4	0.5	0.3	0.4	0.2
		0.8	*1.1*	*0.6*	*1.1*	*0.5*
	Change	-1.2	0	-0.3	-1.0	-7.3
Total mean prominent species cover	1994	30.0	31.0	28.6	25.9	41.6
	1995	11.0	16.6	14.4	5.4	0.3
	Change	-19.0	14.4	-14.2	-20.5	-41.3

Appendix 14 (cont.).

Species	Year/Change	Cover (%)				
		Overall n=32	CN n=8	BO n=12	CH n=8	CB n=4
Total mean other species cover	1994	11.4	11.5	8.9	13.4	13.3
	1995	3.6	5.0	4.2	2.7	1.5
	Change	-7.8	-6.5	-4.7	-10.7	-11.8
Total mean species cover	1994	41.4 *16.4*	42.5 *9.0*	37.5 *13.9*	39.3 *20.4*	54.9 *24.6*
	1995	14.6 *11.0*	21.6 *13.0*	18.6 *8.5*	8.1 *5.3*	1.8 *1.2*
	Change	-26.8	-20.9	-18.9	-31.2	-53.1
Total number of species (*S*)	1994	28	21	21	21	15
	1995	24	20	18	16	6

Appendix 15. Occurrence and change in density for barrens regeneration species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 3. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, and 00 = absent both years.

Species	Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACRU	++	++	0+	0+	00
ACSA	+-	+-	+-	+-	++
AMAR	0+	00	0+	00	00
ASTR	++	+=	0+	00	00
CACO	+0	00	+0	00	00
CAGL	++	+0	++	+=	00
CAOVT	+0	+0	00	00	00
CARA	++	00	+=	0+	00
CATE	++	+=	++	++	0+
CECA	++	++	++	++	++
CEOC	++	+-	+-	++	++
CESC	+-	+-	++	+-	+-
CODR	++	+-	++	++	++
COFL	++	++	++	+-	++
DIVI	++	++	++	++	0+
FRAM	+-	0+	++	++	++
ILDE	0+	00	0+	00	00
JUNI	0+	00	00	00	0+
JUVI	+-	+0	+-	+=	++
MORU	++	00	+=	0+	0+
PAQU	++	++	++	++	++
PRSE	++	++	++	0+	++
QUAL	+=	00	00	+=	00
QUMA	+0	00	00	+0	00
QUPR	+-	++	+-	+-	+-
QURU	+-	++	++	+-	+0
QUST	++	+-	+-	++	++
QUVE	++	+-	+-	++	0+
RHAR	++	+-	++	++	++
RHCA	++	+-	++	++	++

Appendix 15 (cont.).

Species		Overall n=32	CN n=8	BO n=12	CH n=8	CB n=4
RHCO		++	00	++	0+	0+
RHGL		0+	00	00	0+	0+
SAAL		++	+=	++	0+	00
TORA		++	++	++	++	++
ULRU		++	++	++	++	+-
VICI		++	++	++	++	++
VIRU		++	++	++	++	++
Total number of species (S)[a]	1994	33	26	28	24	19
	1995	34	24	31	30	25

[a] S varies from Table 4 S which includes cover species as well.

Appendix 16. Occurrence and change in cover for barrens regeneration species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 3. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, 00 = absent both years, and * = cover present at <0.05%.

Species	Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACRU	+*=	+*=	0+*	0+*	00
ACSA	+-	+-	+-	+-	++
AMAR	0+*	00	0+*	00	00
ASTR	+*=	+*+	0+*	00	00
CACO	+*0	00	+*0	00	00
CAGL	+-*	+-	+*+	+*=	00
CAOVT	+*0	+0	00	00	00
CARA	+*+	00	+*+	0+	00
CATE	+-	+=	+-	+=	0+*
CECA	++	+=	++	++	++
CEOC	+-	+-	+-	++	+-
CESC	+-	+-	+-	+-	+-
CODR	++	++	+-	+=	++
COFL	+-	++	+=	+-	++
DIVI	++	+=	+*+	+=	0+*
FRAM	+*+	0+	+*=	+*+	++
ILDE	+*=	00	+*=	00	00
JUNI	0+*	00	0+*	00	0+
JUVI	+-	+*0	+-*	+=	+=
MORU	+*=	00	+*=	0+*	0+*
PAQU	++	+*+	++	+*+	+*+
PRSE	+*+	+*+	+-*	0+	+*+
QUAL	+*=	00	00	+*=	00
QUMA	+*0	00	00	+*0	00
QUPR	+-	+-	+-	+=	+=
QURU	+-	++	+=	+-	+*+
QUST	+*=	+*=	+*=	+*=	+*+
QUVE	+-	++	+-	+=	+*=
RHAR	+-	++	+-	+=	+-
RHCA	++	+*=	++	++	++

Appendix 16 (cont.).

Species		Overall n=32	CN n=8	BO n=12	CH n=8	CB n=4
RHCO		+*+	0+	+*+	0+*	0+
RHGL		0+	00	00	0+	0+
SAAL		+*=	+*=	+*=	0+*	00
TORA		++	++	++	++	++
ULRU		++	++	++	++	+=
VICI		++	+*+	++	++	++
VIRU		++	++	+*=	+-*	++
Total number of species (S)	1994	34	26	29	24	20
	1995	34	26	32	30	26

Appendix 17. Mean density for prominent barrens regeneration species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 3.

Species	Year/Change	Density (stem/ha)				
		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACSA	1994	7500	9375	5556	11,875	835
		12,930	*12,341*	*9489*	*19,710*	*964*
	1995	6095	6460	3472	7918	9585
		9825	*7889*	*4407*	*13,117*	*18,074*
	Change	-1405	-2915	-2084	-3957	+8750
PAQU	1994	2501	834	5418	626	835
		4170	*1260*	*5691*	*864*	*964*
	1995	10,886	3960	15,832	11,252	9165
		15,098	*2347*	*19,300*	*17,338*	*6735*
	Change	+8385	+3126	+10,414	+10,626	+8330
QUPR	1994	7970	5834	9168	9792	5002
		7474	*4627*	*8484*	*9329*	*4714*
	1995	7448	7500	7917	8544	3750
		5972	*4543*	*8169*	*4581*	*2098*
	Change	-522	+1666	-1251	-1248	-1252
RHAR	1994	12,812	8959	10,000	20,000	14,582
		14,733	*10,386*	*13,817*	*18,749*	*16,064*
	1995	19,844	8542	16,528	30,626	30,832
		25,082	*9573*	*16,213*	*29,854*	*48,865*
	Change	+7032	-417	+6528	+10,626	+16,250
TORA	1994	5000	3541	8472	3126	1250
		9284	*6135*	*13,341*	*5303*	*1595*
	1995	10,261	7709	13,751	10,207	5000
		16,297	*15,274*	*21,285*	*12,862*	*7071*
	Change	+5261	+4168	+5279	+7081	+3750
VICI	1994	938	625	834	1458	832
		1334	*1239*	*1124*	*1650*	*1665*
	1995	9427	3544	10,277	11,665	14,167
		9705	*4028*	*11,802*	*9597*	*8446*
	Change	+8489	+2919	+9443	+10,207	+13,335
VIRU	1994	678	625	278	626	2085
		1396	1239	650	864	3156
	1995	4115	1041	417	418	28,750
		13,847	1526	1443	773	32,269
	Change	+3437	+416	+139	-208	+26,665

Appendix 17 (cont.).

Species	Year/Change	Density (stem/ha)				
		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
Total mean prominent species density	1994	37,399	29,793	39,726	47,503	25,421
	1995	68,076	38,756	68,194	80,630	101,249
	Change	+30,677	+8963	+28,468	+33,127	+75,828
Total mean other species density	1994	30,895	32,300	29,874	28,128	36,677
	1995	43,131	33,551	41,952	43,963	64,181
	Change	+12,236	+1251	+12,078	+15,835	+27,504
Total mean species density	1994	68,294 *22,811*	62,093 *25,831*	69,600 *20,832*	75,631 *26,096*	62,098 *18,318*
	1995	111,207 *55,498*	72,307 *32,613*	110,146 *46,131*	124,593 *36,882*	165,430 *99,647*
	Change	+42,913	+10,214	+40,546	+48,962	+103,332
Total number of species (*S*)[a]	1994	33	26	28	24	19
	1995	34	24	31	30	25

[a] *S* varies from Table 4 *S* which includes cover species as well.

Appendix 18. Mean cover for prominent barrens regeneration species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 3. * = cover present at <0.05%. Change associated with * values is reported to the nearest 0.1%.

		Cover (%)				
Species	Year/Change	Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACSA	1994	1.5	2.9	1.0	1.6	0.1
		2.6	*4.0*	*1.7*	*2.4*	*0.2*
	1995	1.4	2.8	0.8	1.0	1.1
		2.4	*4.2*	*1.1*	*1.2*	*1.8*
	Change	-0.1	-0.1	-0.2	-0.6	+1.0
CECA	1994	0.3	0.2	0.3	0.4	0.5
		0.3	*0.2*	*0.4*	*0.4*	*0.4*
	1995	0.7	0.2	0.5	1.3	0.9
		0.8	*0.1*	*0.8*	*1.0*	*0.5*
	Change	+0.4	0	+0.2	+0.9	+0.4
CEOC	1994	0.9	1.1	1.0	0.4	0.9
		1.3	*1.4*	*1.7*	*0.8*	*0.5*
	1995	0.6	0.9	0.4	0.6	0.8
		0.7	*1.0*	*0.3*	*0.9*	*0.4*
	Change	-0.3	-0.2	-0.6	+0.2	-0.1
COFL	1994	0.7	0.4	0.2	1.2	1.4
		1.8	*0.6*	*0.7*	*3.1*	*2.4*
	1995	0.6	1.1	0.2	0.2	1.7
		1.2	*1.6*	*0.4*	*0.4*	*2.4*
	Change	-0.1	+0.7	0.0	-1.0	+0.3
PAQU	1994	0.1	*	0.3	*	*
		0.3		*0.4*		
	1995	1.0	0.4	1.1	1.4	0.8
		1.4	*0.4*	*1.4*	*2.1*	*0.9*
	Change	+0.9	+0.4	+0.8	+1.4	+0.8
RHAR	1994	3.5	1.6	3.9	5.3	2.5
		4.3	*1.7*	*4.8*	*5.5*	*3.2*
	1995	3.3	1.9	3.3	5.3	2.2
		4.6	*2.1*	*5.1*	*5.9*	*3.4*
	Change	-0.2	+0.3	-0.6	0.0	-0.3

Appendix 18 (cont.).

Species	Year/Change	Cover (%)				
		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
TORA	1994	1.3 *2.3*	0.6 *1.4*	1.8 *2.9*	1.6 *2.6*	0.1 *0.2*
	1995	1.5 *2.6*	1.2 *2.8*	2.0 *3.0*	1.8 *2.6*	0.5 *0.7*
	Change	+0.2	+0.6	+0.2	+0.2	+0.4
VICI	1994	0.1 *0.2*	*	0.2 *0.4*	0.1 *0.1*	0.1 *0.2*
	1995	0.6 *0.6*	0.3 *0.2*	0.5 *0.5*	1.1 *0.7*	0.6 *0.4*
	Change	+0.5	+0.3	+0.3	+1.0	+0.5
VIRU	1994	0.1 *0.1*	0.1 *0.2*	*	0.1 *0.1*	0.1 *0.1*
	1995	0.3 *1.1*	0.2 *0.4*	*	*	2.2 2.6
	Change	+0.2	+0.1	+0.0	-0.1	+2.1
Total mean prominent species cover	1994	8.5	6.9	8.7	10.7	5.7
	1995	10.0	9.0	8.8	12.7	10.8
	Change	+1.5	+2.1	+0.1	+2.0	+5.1
Total mean other species cover	1994	3.0	2.9	3.9	3.2	1.4
	1995	3.8	3.8	3.8	4.0	3.2
	Change	+0.8	+0.9	-0.1	+0.8	+1.8
Total mean species cover	1994	11.5 *7.0*	9.8 *4.2*	12.6 *8.2*	13.9 *8.3*	7.1 *3.2*
	1995	13.8 *7.2*	12.8 *6.9*	12.6 *7.9*	16.7 *7.1*	14.0 *6.3*
	Change	+2.3	+3.0	0.0	+2.8	+6.9
Total number of species (*S*)	1994	34	26	29	24	20
	1995	34	26	32	30	26

Appendix 19. Occurrence and change in basal area for glade tree species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 4. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, 00 = absent both years, and * = basal area present at <0.05 m^2/ha.

Species		Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
CAOVT		+*=	00	+=	00	00
CATE		+=	00	+=	+=	00
CECA		+-	+0	+=	+-	+0
DIVI		+*=	00	+=	00	00
FRAM		+=	+=	+=	00	00
FRQU		+=	+=	00	00	00
JUVI		+-	+=	+=	+0	+0
QUPR		+-	00	+=	+0	+=
QUST		+=	00	00	+=	00
QUVE		+*=	00	+=	00	00
RHCA		+*=	+=	00	00	00
RHCO		+*=	00	00	+=	00
Total number of species (*S*)[a]	1994	12	5	8	6	3
	1995	12	4	8	4	1

[a] *S* varies from Table 5 *S* which includes cover species as well.

Appendix 20. Occurrence and change in density for glade tree species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 4. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, and 00 = absent both years.

Species		Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
CAOVT		+=	00	+=	00	00
CATE		+-	00	+=	+-	00
CECA		+-	+0	+=	+-	+0
DIVI		+=	00	+=	00	00
FRAM		+=	+=	+=	00	00
FRQU		+=	+=	00	00	00
JUVI		+-	+=	+=	+0	+0
QUPR		+-	00	+=	+0	+=
QUST		+=	00	00	+=	00
QUVE		+=	00	+=	00	00
RHCA		+=	+=	00	00	00
RHCO		+=	00	00	+=	00
Total number of species (*S*)[a]	1994	12	5	8	6	3
	1995	12	4	8	4	1

[a] *S* varies from Table 5 *S* which includes cover species as well.

Appendix 21. Occurrence and change in cover for glade tree species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 4. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, 00 = absent both years, and * = cover present at <0.05%.

Species		Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
ACSA		+=	+=	+=	00	00
CAOVT		+-	00	+-	00	00
CATE		+-	+-	+=	+-	+-
CECA		+-	++	++	+-	+0
COFL		+*=	00	+=	00	00
DIVI		+-	00	+=	00	+-
FRAM		++	++	++	0+	++
FRQU		++	++	00	00	00
JUVI		+-	+-	++	+-	+0
QUPR		+-	+-	++	+-	++
QURU		0+*	00	0+	00	00
QUST		+=	00	00	+-	0+
QUVE		+=	00	+-	00	00
RHCA		++	+=	00	+-	+0
RHCO		+=	00	00	+-	00
Total number of species (*S*)	1994	14	8	10	7	7
	1995	15	8	11	8	5

Appendix 22. Mean basal area for prominent glade tree species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 4.

		Basal area (m^2/ha)				
Species	Year/Change	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
CECA	1994	0.5	0.1	0.1	1.3	0.6
		1.2	*0.1*	*0.3*	*2.3*	*0.9*
	1995	0.3	0.0	0.1	1.2	0.0
		1.2	*0.0*	*0.3*	*2.4*	*0.0*
	Change	-0.2	-0.1	0.0	-0.1	-0.6
FRAM	1994	0.4	0.5	1.3	0.0	0.0
		1.0	*1.0*	*1.6*	*0.0*	*0.0*
	1995	0.4	0.5	1.3	0.0	0.0
		1.0	*1.0*	*1.6*	*0.0*	*0.0*
	Change	0.0	0.0	0.0	0.0	0.0
JUVI	1994	7.3	8.0	7.7	4.0	9.5
		5.2	*6.0*	*4.0*	*1.6*	*7.7*
	1995	3.9	8.0	7.7	0.0	0.0
		5.2	*6.0*	*4.0*	*0.0*	*0.0*
	Change	-3.4	0.0	0.0	-4.0	-9.5
QUPR	1994	0.2	0.0	0.3	0.4	0.1
		0.4	*0.0*	*0.4*	*0.8*	*0.2*
	1995	0.1	0.0	0.3	0.0	0.1
		0.2	*0.0*	*0.4*	*0.0*	*0.2*
	Change	-0.1	0.0	0.0	-0.4	0.0
QUST	1994	0.4	0.0	0.0	1.7	0.0
		1.7	*0.0*	*0.0*	*3.4*	*0.0*
	1995	0.4	0.0	0.0	1.7	0.0
		1.7	*0.0*	*0.0*	*3.4*	*0.0*
	Change	0.0	0.0	0.0	0.0	0.0
Total mean prominent species basal area	1994	8.8	8.6	9.4	7.4	10.2
	1995	5.1	8.5	9.4	2.9	0.1
	Change	-3.7	-0.1	0	-4.5	-10.1
Total mean other species basal area	1994	0.4	0.3	0.6	0.3	0.1
	1995	0.4	0.3	0.6	0.2	0
	Change	0	0	0	-0.1	-0.1

Appendix 22 (cont.).

Species	Year/Change	Basal area (m^2/ha)				
		Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
Total mean species basal area	1994	9.2 *5.2*	8.9 *5.8*	10.0 *5.5*	7.7 *3.8*	10.3 *7.2*
	1995	5.5 *5.7*	8.8 *5.8*	10.0 *5.5*	3.1 *3.4*	0.1 *0.2*
	Change	-3.7	-0.1	0.0	-4.6	-10.2
Total number of species (*S*)[a]	1994	12	5	8	6	3
	1995	12	4	8	4	1

[a] *S* varies from Table 5 *S* which includes cover species as well.

Appendix 23. Mean density for prominent glade tree species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 4.

		Density (stem/ha)				
Species	Year/Change	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
CECA	1994	75	25	25	150	100
		139	*50*	*50*	*238*	*141*
	1995	38	0	25	125	0
		126	*0*	*50*	*250*	*0*
	Change	-37	-25	0	-25	-100
FRAM	1994	50	50	150	0	0
		115	*100*	*191*	*0*	*0*
	1995	50	50	150	0	0
		115	*100*	*191*	*0*	*0*
	Change	0	0	0	0	0
JUVI	1994	675	700	800	575	625
		289	*408*	*141*	*377*	222
	1995	375	700	800	0	0
		434	*408*	*141*	*0*	*0*
	Change	-300	0	0	-575	-625
QUPR	1994	25	0	50	25	25
		45	*0*	*58*	*50*	*50*
	1995	19	0	50	0	25
		40	*0*	*58*	*0*	*50*
	Change	-6	0	0	-25	0
QUST	1994	12	0	0	50	0
		50	*0*	*0*	*100*	*0*
	1995	12	0	0	50	0
		50	*0*	*0*	*100*	*0*
	Change	0	0	0	0	0
Total mean prominent species density	1994	837	775	1025	800	750
	1995	494	750	1025	175	25
	Change	-343	-25	0	-625	-725
Total mean other species density	1994	75	75	100	125	0
	1995	68	75	100	100	0
	Change	-7	0	0	-25	0

Appendix 23 (cont.).

Species	Year/Change	Density (stem/ha)				
		Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
Total mean species density	1994	912 *350*	850 *451*	1125 *222*	925 *435*	750 *265*
	1995	562 *514*	825 *457*	1125 *222*	275 *222*	25 *50*
	Change	-350	-25	0	-650	-725
Total number of species (*S*)[a]	1994	12	5	8	6	3
	1995	12	4	8	4	1

[a] *S* varies from Table 5 *S* which includes cover species as well.

Appendix 24. Mean cover for prominent glade tree species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 4.

Species	Year/Change	Cover (%)				
		Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
CECA	1994	1.7 *3.3*	0.2 *0.3*	0.8 *1.5*	3.2 *5.9*	2.5 *3.3*
	1995	0.8 *1.7*	0.9 *1.4*	0.9 *1.4*	1.5 *3.0*	0.0 *0.0*
	Change	-0.9	+0.7	+0.1	-1.7	-2.5
FRAM	1994	2.4 *3.6*	1.2 *2.5*	4.5 *4.2*	0.0 *0.0*	4.0 *4.8*
	1995	3.2 *5.2*	1.8 *3.5*	5.5 *4.5*	0.2 *0.5*	5.4 *8.5*
	Change	+0.8	+0.6	+1.0	+0.2	+1.4
JUVI	1994	31.5 *10.9*	38.8 *11.8*	29.0 *6.1*	21.8 *10.7*	36.5 *7.7*
	1995	16.7 *18.2*	37.2 *11.4*	29.5 *3.8*	0.1 *0.2*	0.0 *0.0*
	Change	-14.8	-1.6	+0.5	-21.7	-36.5
QUPR	1994	3.8 *5.5*	5.5 *6.7*	6.0 *8.5*	1.8 *3.5*	1.8 *1.3*
	1995	3.5 *5.2*	5.0 *3.6*	6.4 *9.4*	0.1 *0.2*	2.5 2.5
	Change	-0.3	-0.5	+0.4	-1.7	+0.7
QUST	1994	1.2 *5.0*	0.0 *0.0*	0.0 *0.0*	5.0 *10.0*	0.0 *0.0*
	1995	0.9 *3.5*	0.0 *0.0*	0.0 *0.0*	3.5 *7.0*	0.2 *0.5*
	Change	-0.3	0.0	0.0	-1.5	+0.2
Total mean prominent species cover	1994	40.6	45.7	40.3	31.8	44.8
	1995	25.1	44.9	42.3	5.4	8.1
	Change	-15.5	-0.8	+2.0	-26.4	-36.7
Total mean other species cover	1994	2.9	2.9	3.8	2.5	2.1
	1995	2.6	4.0	3.5	1.5	1.3
	Change	-0.3	+1.1	-0.3	-1.0	-0.8

Appendix 24 (cont.).

		Cover (%)				
Species	Year/Change	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
Total mean species cover	1994	43.5 *13.7*	48.6 *16.5*	44.1 *7.6*	34.3 *17.0*	46.9 *12.3*
	1995	27.7 *22.6*	48.9 *13.1*	45.8 *11.6*	6.9 *6.5*	9.4 *12.5*
	Change	-15.8	+0.3	+1.7	-27.4	-37.5
Total number of species (*S*)	1994	14	8	10	7	7
	1995	15	8	11	8	5

Appendix 25. Occurrence and change in density for glade sapling/shrub species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 4. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, and 00 = absent both years.

Species		Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
ACSA		+=	+=	00	00	00
CAOVL		+=	+=	00	00	00
CAOVT		+-	+=	00	+=	00
CATE		+=	0+	+-	+=	00
CECA		+-	00	+=	0+	+0
CEOC		+-	++	+-	00	+0
CESC		+=	+=	00	00	00
CODR		+-	+-	+-	+-	+0
DIVI		+-	+=	+-	+-	00
FRAM		0+	0+	00	00	00
JUNI		+=	+=	+=	00	00
JUVI		+-	+=	+-	+0	+0
PTTR		+-	00	+-	00	00
QUPR		+-	+-	+-	00	+-
QURU		+-	+=	+0	00	00
QUST		+0	00	00	+0	+0
QUVE		+=	+=	+=	00	00
RHAR		+-	++	+-	00	+0
RHCA		+-	++	+-	+=	+0
RHCO		+-	+-	+-	+-	+-
RHGL		+-	+=	00	00	+0
VICI		+-	+-	00	00	00
Total number of species (S)[a]	1994	21	17	14	8	10
	1995	21	19	13	7	2

[a] S varies from Table 6 S which includes cover species as well.

Appendix 26. Occurrence and change in cover for glade sapling/shrub species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 4. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, 00 = absent both years, and * = cover present at <0.05%.

Species		Overall n=16	CN n=4	BO n=4	CH n=4	CB n=4
ACSA		+-*	+-	00	00	00
CAOVL		+=	+=	00	00	00
CAOVT		+-*	+0	00	+=	00
CATE		+-	0+	+=	+=	+0
CECA		+-	00	++	0+	+0
CEOC		+=	+=	+=	00	+0
CESC		+-*	+-	00	00	00
CODR		+-	+-	+-	+-	+0
DIVI		+=	++	++	+-	+0
FRAM		0+*	0+	00	00	00
JUNI		++	++	+=	00	00
JUVI		+-	+-	+-	+0	+0
PTTR		+-*	00	+-	00	00
QUPR		+-	+-	+-	00	+-
QURU		+-*	+-	+0	00	00
QUST		+0	00	00	+0	+0
QUVE		+=	+-	+=	00	00
RHAR		+-	++	+-	00	+0
RHCA		+-	+=	+-	+-	+0
RHCO		+-	+-	+-	+-	+-
RHGL		+-	+=	00	00	+0
VICI		+-	+-	++	00	+0
Total number of species (S)	1994	21	17	15	8	13
	1995	21	18	14	7	2

Appendix 27. Mean density for prominent glade sapling/shrub species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 4.

		Density (stem/ha)				
Species	Year/Change	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
CODR	1994	481 *550*	725 *998*	475 *263*	250 *332*	475 *435*
	1995	269 *494*	675 *907*	275 *171*	125 *150*	0 *0*
	Change	-212	-50	-200	-125	-475
JUVI	1994	1469 *1114*	2550 *1415*	1400 *739*	1350 *904*	575 *435*
	1995	944 *1323*	2550 *1491*	1225 *780*	0 *0*	0 *0*
	Change	-525	0	-175	-1350	-575
QUPR	1994	194 *334*	275 *359*	125 *957*	0 *0*	375 *556*
	1995	100 *183*	250 *311*	100 *115*	0 *0*	50 *100*
	Change	-94	-25	-25	0	-325
RHAR	1994	188 *424*	100 *200*	425 *785*	0 *0*	225 *330*
	1995	88 *25*	225 *450*	125 *250*	0 *0*	0 *0*
	Change	-100	+125	-300	0	-225
RHCO	1994	475 *422*	475 *629*	475 *96*	725 *457*	225 *330*
	1995	269 *265*	125 *96*	325 *150*	550 *332*	75 *150*
	Change	-206	-350	-150	-175	-150
Total mean prominent species density	1994	2807	4125	2900	2325	1875
	1995	1670	3825	2050	675	125
	Change	-1137	-300	-850	-1650	-1750
Total mean other species density	1994	649	1050	800	200	550
	1995	493	1175	575	225	0
	Change	-156	+125	-225	+25	-550

Appendix 27 (cont.).

Species	Year/Change	Density (stem/ha) Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
Total mean species density	1994	3456 *1484*	5175 *936*	3700 *606*	2525 *1159*	2425 *1352*
	1995	2163 *2145*	5000 *1804*	2625 *842*	900 *577*	125 *150*
	Change	-1293	-175	-1075	-1625	-2300
Total number of species (*S*)[a]	1994	21	17	14	8	10
	1995	21	19	13	7	2

[a] *S* varies from Table 6 *S* which includes cover species as well.

Appendix 28. Mean cover for prominent glade sapling/shrub species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 4.

		Cover (%)				
Species	Year/Change	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
CODR	1994	2.5 *4.2*	4.9 *8.1*	1.6 *1.1*	0.9 *1.4*	2.8 *2.7*
	1995	1.5 *3.9*	4.8 *7.5*	0.8 *0.3*	0.4 *0.5*	0 *0*
	Change	-1.0	-0.1	-0.8	-0.5	-2.8
JUVI	1994	11.1 *7.9*	16.8 *9.5*	9.8 *6.6*	13.2 *7.3*	4.8 *4.3*
	1995	5.9 *8.4*	16.0 *8.8*	7.8 *6.2*	0 *0*	0 *0*
	Change	-5.2	-0.8	-2.0	-13.2	-4.8
QUPR	1994	2.4 *4.2*	3.0 *1.8*	0.8 *0.9*	0 *0*	5.8 *7.6*
	1995	0.9 *1.3*	2.2 *1.7*	0.4 *0.5*	0 *0*	0.9 *1.4*
	Change	-1.5	-0.8	-0.4	0	-4.9
RHAR	1994	0.8 *1.6*	0.2 *0.5*	1.4 *2.4*	0 *0*	1.5 *1.9*
	1995	0.2 *0.5*	0.5 *1.0*	0.2 *0.5*	0 *0*	0 *0*
	Change	-0.6	+0.3	-1.2	0	-1.5
RHCO	1994	4.8 *5.9*	2.6 *3.7*	3.2 *0.5*	8.9 *7.0*	4.6 *8.9*
	1995	1.4 *2.0*	0.5 *0.4*	1.5 *1.0*	3.4 *3.1*	0.1 *0.2*
	Change	-3.4	-2.1	-1.7	-5.5	-4.5
Total mean prominent species cover	1994	21.6	27.5	16.8	23.0	19.5
	1995	9.9	24.0	10.7	3.8	1.0
	Change	-13.0	-4.1	-6.2	-19.6	-22.3
Total mean other species cover	1994	4.8	9.8	3.8	1.6	3.8
	1995	3.5	9.2	3.7	1.2	0
	Change	-1.3	-0.6	-0.1	-0.4	-3.8

Appendix 28 (cont.).

Species	Year/Change	Cover (%)				
		Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
Total mean species cover	1994	26.4 *11.0*	37.3 *2.3*	20.6 *6.9*	24.6 *9.8*	23.3 *15.4*
	1995	13.4 *13.3*	33.2 *4.7*	14.4 *4.9*	5.0 *3.5*	1.0 *1.4*
	Change	-13.0	-4.1	-6.2	-19.6	-22.3
Total number of species (*S*)	1994	21	17	15	8	13
	1995	21	18	14	7	2

Appendix 29. Occurrence and change in density for glade regeneration species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 4. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, and 00 = absent both years.

Species		Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
ACSA		+-	+-	+-	00	00
CAGL		+=	00	0+	00	+0
CATE		++	++	++	00	+0
CECA		++	++	++	++	++
CEOC		++	++	++	++	+-
CESC		++	++	0+	+0	+=
CODR		++	++	++	00	++
DIVI		+-	+0	++	+0	00
FRAM		+=	+=	00	00	00
FRQU		0+	0+	00	00	00
JUNI		+0	00	+0	00	00
JUVI		+-	+-	+-	+-	+-
PAQU		++	++	0+	00	0+
PRSE		++	++	00	00	+0
QUAL		+0	00	00	00	+0
QUPR		+-	++	++	++	+-
QURU		0+	00	0+	00	00
QUST		++	++	++	++	++
QUVE		+-	++	+-	+-	+0
RHAR		++	+-	++	++	++
RHCA		+-	+-	+-	++	00
RHCO		++	0+	0+	++	0+
RHGL		0+	00	00	00	0+
TORA		+=	+0	0+	00	00
ULRU		+-	+-	+=	00	+0
VICI		++	00	0+	0+	+0
Total number of species (*S*)[a]	1994	23	18	14	11	15
	1995	24	18	20	10	11

[a] *S* varies from Table 7 *S* which includes cover species as well.

Appendix 30. Occurrence and change in cover for glade regeneration species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 4. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, 00 = absent both years, and * = cover present at <0.05%.

Species		Overall n=16	CN n=4	BO n=4	CH n=4	CB n=4
ACSA		+=	+=	+-	00	00
CAGL		+*=	00	0+*	00	+*0
CATE		+=	+-	+=	00	+0
CECA		++	++	++	+=	++
CEOC		+-	+=	++	+-	+-
CESC		+-	+-	0+*	+*0	+*=
CODR		++	++	++	+-	++
COFL		+0	00	00	00	+0
DIVI		+*=	+*0	+*+	+*0	00
FRAM		+-*	+=	0+*	00	00
FRQU		0+*	0+*	00	00	00
JUNI		+*0	00	+*0	00	00
JUVI		+-*	+*+	+-*	+-*	+-*
PAQU		+*=	+-*	0+*	00	0+
PRSE		+*=	+=	00	00	+*0
QUAL		+*0	00	00	00	+*0
QUPR		+-	++	+-	+=	+-
QURU		+*=	00	0+*	+*=	00
QUST		+=	+=	+=	+=	+-
QUVE		+-	+=	+-	+=	+0
RHAR		+-	+-	++	+-	+-
RHCA		+-	+-	+-*	+=	+-*
RHCO		++	0+*	++	++	0+
RHGL		0+*	00	00	00	0+
TORA		+*=	+*0	0+*	00	00
ULRU		+*=	+=	+*=	00	+*0
VICI		+*=	+*=	0+*	0+*	+*=
Total number of species (S)	1994	25	19	15	13	17
	1995	24	19	21	12	13

Appendix 31. Mean density for prominent glade regeneration species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 4.

		Density (stem/ha)				
Species	Year/Change	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
CECA	1994	2813 *4204*	2500 *3193*	832 *1665*	1253 *835*	6668 *6803*
	1995	5313 *7434*	6668 *7073*	2915 *2097*	2085 *3155*	9582 *12,792*
	Change	+2500	+4168	+2083	+833	+2914
CEOC	1994	3333 *3160*	4165 *2885*	5000 *3845*	1668 *1360*	2500 *3966*
	1995	4897 *4193*	6668 *4303*	8335 *4714*	2500 *2152*	2085 *2097*
	Change	+1564	+2503	+4170	+832	-415
CODR	1994	313 *673*	418 *835*	418 *835*	0 *0*	418 *835*
	1995	2084 *3776*	2085 *2097*	1668 *1360*	0 *0*	4582 *7120*
	Change	+1771	+1667	+1250	0	+4164
QUPR	1994	7812 *7593*	3752 *3437*	9997 *7070*	6668 *6806*	10,832 *11,744*
	1995	7708 *7932*	5832 *5183*	12,917 *7121*	7082 *12,047*	5000 *6382*
	Change	-104	+2080	+2920	+414	-5832
RHAR	1994	24,375 *34,328*	5000 *8922*	25,832 *20,749*	2918 *5835*	63,750 *46,513*
	1995	51,250 *85,372*	4585 *5674*	43,332 *35,354*	6250 *9267*	150,830 *127,140*
	Change	+26,875	-415	+17,500	+3332	+87,080
RHCO	1994	208 *832*	0 *0*	0 *0*	832 *1665*	0 *0*
	1995	4166 *8647*	418 *835*	4165 *3468*	3750 *6437*	8332 *16,665*
	Change	+3958	+418	+4165	+2918	+8332
Total mean prominent species density	1994	38,854	15,835	42,079	13,339	84,168
	1995	75,418	26,256	73,332	21,667	172,079
	Change	+36,564	+10,421	+31,253	+8328	+87,911

Appendix 31 (cont.).

Species	Year/Change	Density (stem/ha)				
		Overall n=16	CN n=4	BO n=4	CH n=4	CB n=4
Total mean other species density	1994	9796	17,920	9591	4171	7507
	1995	10,422	19,174	13,756	4171	12,921
	Change	+626	+1254	+4165	0	+5414
Total mean species density	1994	48,650 *43,488*	33,755 *22,322*	51,670 *28,827*	17,510 *12,811*	91,675 *62,399*
	1995	85,840 *89,709*	45,430 *29,354*	87,088 *38,387*	25,838 *32,471*	185,000 *129,453*
	Change	+37,190	+11,675	+35,418	+8328	+93,325
Total number of species (S)[a]	1994	23	18	14	11	15
	1995	24	18	20	10	11

[a] S varies from Table 7 S which includes cover species as well.

Appendix 32. Mean cover for prominent glade regeneration species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 4. * = cover present at <0.05%. Change associated with * values is reported to the nearest 0.1%.

Species	Year/Change	Cover (%)				
		Overall n=16	CN n=4	BO *n*=4	CH *n*=4	CB *n*=4
CECA	1994	0.1 *0.1*	0.1 *0.2*	0.1 *0.2*	0.1 *0.04*	0.1 *0.1*
	1995	0.8 *2.3*	0.5 *0.4*	0.3 *0.3*	0.1 *0.1*	2.6 *4.5*
	Change	+0.7	+0.4	+0.2	0	+2.5
QUPR	1994	1.2 *1.1*	0.6 *0.7*	1.9 *1.6*	0.6 *0.7*	1.6 *1.0*
	1995	1.0 *1.0*	1.0 *1.0*	1.3 *1.2*	0.6 *1.0*	1.0 *0.9*
	Change	-0.2	+0.4	-0.6	0	-0.6
RHAR	1994	8.2 *9.9*	2.8 *5.1*	7.2 *7.4*	1.8 *2.9*	21.1 *9.3*
	1995	6.5 *8.9*	1.5 *2.1*	9.4 *8.8*	0.8 *1.2*	14.0 *12.1*
	Change	-1.7	-1.3	+2.2	-1.0	-7.1
RHCO	1994	0.1 *0.2*	0 *0*	0.1 *0.2*	0.2 *0.4*	0 *0*
	1995	1.4 *3.5*	*	1.3 *1.6*	0.9 *1.4*	3.5 *7.0*
	Change	+1.3	+0.0	+1.2	+0.7	+3.5
Total mean prominent species cover	1994	9.6	3.5	9.3	2.7	22.8
	1995	9.7	3.0	12.3	2.4	21.1
	Change	+0.1	-0.5	+3.0	-0.3	-1.7
Total mean other species cover	1994	2.6	4.1	3.2	1.4	1.9
	1995	2.0	3.6	2.6	0.5	1.5
	Change	-0.6	-0.5	-0.6	-0.9	-0.4
Total mean species cover	1994	12.2 *11.4*	7.6 *8.4*	12.5 *12.0*	4.1 *3.1*	24.7 *10.3*
	1995	11.7 *11.7*	6.6 *5.0*	14.9 *12.5*	2.9 *3.9*	22.6 *13.3*
	Change	-0.5	-1.0	+2.4	-1.2	-2.1
Total number of species (*S*)	1994	25	19	15	13	17
	1995	24	19	21	12	13

Appendix 33. Occurrence and change in cover for barrens herbaceous species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 3. Non-native and state listed species are noted. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, 00 = absent both years, and * = cover present at <0.05%.

Species	Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACAGRA	++	+*+	+*+	++	++
AGATEN	0+	00	00	0+	00
AGRPUB	+*+	00	+*+	+=	00
AGRROS	++	++	++	++	++
AMPBRA	+=	++	+=	+*+	00
ANEVIR	+*+	+*=	+*=	+*+	0+*
ANTPLA	+=	+=	+*=	+*=	+*+
ARISER	+*=	+*=	0+*	+*=	00
ASPPLA	+*=	+*=	+*=	00	+*=
ASTANO	++	++	+=	++	++
ASTPAT	+*+	00	+*=	+*+	++
ASTTUR	+*+	00	++	+*=	00
BOTVIR	+*=	00	+*=	+*0	00
BOUCUR	0+*	00	00	0+*	00
BROPUB	++	+=	+=	++	+*+
CARBLA	+*=	+*=	+*=	0+*	00
CARSPP	++	+*+	++	++	++
CASFAS	+*+	00	0+*	+*+	00
CEAAME	+*=	00	+*=	+*+	00
CHAMAC	0+	00	00	0+*	00
CHEALB	0+*	00	00	0+*	00
CIRALT	0+*	00	00	0+*	00
COCCAR	+*=	00	+*=	00	00
CONCAN	0+*	00	00	0+	0+
CROGLA	0+*	00	00	00	0+
CROMON	0+*	00	00	0+*	0+
CUNORI	+*=	+*=	+*=	0+*	0+*
DESGLA	++	+*0	++	++	0+*
DESGLU	+-	++	+-	+-	0+*
DESNUD	+=	+*=	++	+=	00
DESPAN	+*=	00	0+*	+*=	00
DICACU	+*+	+*=	+*=	++	0+
DICBOS	++	0+*	++	++	++

Appendix 33 (cont.).

Species	Overall n=32	CN n=8	BO n=12	CH n=8	CB n=4
DIOQUA	+•0	+0	+•0	+0	00
ELYVIR	+•=	+•=	+•=	+•+	0+
ERACAP	0+•	00	00	0+•	00
EREHIE	0+	0+•	0+	0+	0+
ERIANN	0+	00	00	0+	0+
EUPCOR	+•=	00	0+•	+•=	00
EUPPER	0+•	00	00	0+•	00
EUPRUG	0+•	00	0+•	0+	0+
FESOBT	+=	+-•	++	++	+•=
GALCIR	++	++	++	++	+=
GALPIL	0+•	00	00	0+•	0+•
GALREG	+•=	00	00	+•=	00
GALTRI	+•=	00	+•=	00	00
GEUCAN	++	+=	+•+	+•+	++
GLACAN	0+	00	00	0+	0+
HEDNUT	+•=	00	+•=	00	0+•
HELDIV	++	++	++	++	++
IPOPAN	0+•	00	00	0+	00
LACCAN	0+•	00	0+•	0+	00
LACFLO	0+•	0+•	0+•	0+•	00
LACSER[x]	0+•	00	00	00	0+•
LESPRO	+•=	00	+•=	0+•	0+
LESSPP	+-	+•=	+-	++	00
LESVIR	+•+	00	+•=	++	+•=
LEUMUL	0+•	00	00	0+	0+
LITCAN	+•=	00	00	+-•	00
MONBRA	++	++	++	++	++
MUHSOB	++	+=	++	++	++
OXADIL	0+•	00	00	00	0+•
PANFLE	0+•	00	00	0+•	00
PASLUT	+•+	+•=	+•+	+•=	+•=
PELATR	+•=	+•=	00	00	00
PENPAL	+•=	+•=	00	+•+	0+
PHRLEP	+•+	+•+	0+	+-•	0+•
PHYAME	0+•	00	00	00	0+•

Appendix 33 (cont.).

Species		Overall n=32	CN n=8	BO n=12	CH n=8	CB n=4
PHYHET		0+	00	00	0+	0+
PHYVIR		0+*	00	00	0+*	00
POIDEN		+*+	0+*	+*+	+*+	++
PYCPIL		+*0	00	00	+*0	00
RATPIN		+*=	+*=	+*+	00	00
ROSCAR[w]		+*+	+*+	+*0	+=	00
ROSMUL[x,w]		+*=	00	+*=	00	+-*
RUBENS[w]		+*+	00	++	0+*	0+
RUEHUM		+*=	0+*	+*=	+*+	00
SANCAN		++	++	++	++	++
SCHSCO		+*=	00	00	+*=	00
SENPLA		++	+=	+*+	++	++
SETVIR[x]		0+*	00	0+*	00	00
SMIHIS[w]		+-*	+=	0+	+=	+*=
SOLGIG		0+*	00	00	0+	0+
SOLPET		++	++	+=	00	++
SOLPTY		0+*	00	00	0+*	00
SOLRAD		+*=	00	00	+*=	00
SOLULM		++	++	++	++	++
SORNUT		0+*	00	00	00	0+*
SYMORB[w]		+=	+-	+=	+-	++
TRIAUR		+*+	00	++	00	00
TRIFLA		0+*	0+*	00	0+*	00
VERHEL		+*=	00	+*=	00	00
VERTHA[x]		0+	00	00	0+	0+
VIOPRA		+*0	00	+*0	00	00
VIOSOR		+*=	0+*	+=	00	00
VIOTRI		+*=	0+*	+*0	00	00
WOOOBT		+*=	00	+*=	00	00
Total number of species (S)	1994	66	37	53	48	25
	1995	94	43	60	74	52

[x] Exotic.
[w] Should have been recorded and analyzed with woody vegetation.

Appendix 34. Mean cover for prominent barrens herbaceous species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 3. * = cover present at <0.05%. Change associated with * values is reported to the nearest 0.1%.

		Cover (%)				
Species	Year/Change	Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
ACAGRA	1994	0.1 *0.1*	*	*	0.1 *0.1*	0.1 *0.1*
	1995	0.3 *1.1*	0.1 *0.1*	0.1 *0.1*	0.3 *0.3*	1.7 *3.1*
	Change	+0.2	+0.1	+0.1	+0.2	+1.6
AGRROS	1994	0.3 *0.3*	0.2 *0.3*	0.4 *0.4*	0.2 *0.3*	0.1 *0.3*
	1995	0.7 *0.9*	0.8 *1.0*	1.0 *1.1*	0.3 *0.3*	0.4 *0.8*
	Change	+0.4	+0.6	+0.6	+0.1	+0.3
AMPBRA	1994	0.3 *0.8*	0.1 *0.2*	0.6 *1.3*	*	0.0 *0.0*
	1995	0.3 *0.7*	0.2 *0.4*	0.6 *1.0*	0.1 *0.1*	0.0 *0.0*
	Change	0.0	+0.1	0	+0.1	0.0
DESGLU	1994	0.5 *1.4*	0.2 *0.3*	0.7 *1.7*	0.7 *1.7*	0.0 *0.0*
	1995	0.4 *0.9*	0.6 *0.9*	0.6 *1.2*	0.2 *0.4*	*
	Change	-0.1	+0.4	-0.1	-0.5	+0.0
DICBOS	1994	0.1 *0.1*	0.0 *0.0*	0.1 *0.1*	0.1 *0.1*	0.3 *0.2*
	1995	0.5 *0.8*	*	0.4 *0.5*	0.4 *0.5*	1.7 *1.4*
	Change	+0.4	+0.0	+0.3	+0.3	+1.4
EREHIE	1994	0.0 *0.0*	0.0 *0.0*	0.0 *0.0*	0.0 *0.0*	0.0 *0.0*
	1995	0.4 *1.1*	*	0.1 *0.1*	1.2 2.0	0.5 *0.7*
	Change	+0.4	+0.0	+0.1	+1.2	+0.5

Appendix 34 (cont.).

Species	Year/Change	Cover (%)				
		Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
GALCIR	1994	0.4 *0.2*	0.4 *0.3*	0.4 *0.1*	0.4 *0.2*	0.3 *0.1*
	1995	0.5 *0.3*	0.4 *0.3*	0.6 *0.3*	0.6 *0.4*	0.3 *0.2*
	Change	+0.1	0.0	+0.2	+0.2	0.0
GLACAN	1994	0.0 *0.0*	0.0 *0.0*	0.0 *0.0*	0.0 *0.0*	0.0 *0.0*
	1995	0.3 *1.0*	0.0 *0.0*	*	0.3 *0.5*	1.5 *2.6*
	Change	+0.3	0.0	+0.0	+0.3	+1.5
HELDIV	1994	0.7 *1.1*	0.2 *0.2*	0.7 *0.9*	0.8 *1.1*	1.4 *2.1*
	1995	2.4 *3.6*	0.9 *1.7*	2.4 *4.8*	3.0 *2.1*	4.4 *4.2*
	Change	+1.7	+0.7	+1.7	+2.2	+3.0
MONBRA	1994	0.3 *0.5*	0.1 *0.3*	0.3 *0.3*	0.5 *0.7*	0.3 *0.3*
	1995	0.6 *1.0*	0.2 *0.6*	0.5 *0.6*	1.0 *1.6*	0.6 *0.7*
	Change	+0.3	+0.1	+0.2	+0.5	+0.3
MUHSOB	1994	0.5 *0.8*	0.3 *0.7*	0.3 *0.5*	0.7 *0.7*	1.0 *1.7*
	1995	1.6 *2.3*	0.3 *0.5*	0.6 *0.8*	3.3 *2.4*	3.6 *4.3*
	Change	+1.1	0.0	+0.3	+2.6	+2.6
POIDEN	1994	*	0.0 *0.0*	*	*	0.1 *0.1*
	1995	0.9 *2.8*	*	0.1 *0.1*	2.3 *4.5*	2.6 *4.3*
	Change	+0.9	+0.0	+0.1	+2.3	+2.5
SOLPET	1994	0.2 *0.4*	0.3 *0.4*	0.2 *0.6*	0.0 *0.0*	0.3 *0.5*
	1995	0.4 *0.8*	0.3 *0.5*	0.2 *0.7*	0.0 *0.0*	1.5 *1.3*
	Change	+0.2	0.0	0.0	0.0	+1.2

Appendix 34 (cont.).

Species	Year/Change	Cover (%) Overall *n*=32	CN *n*=8	BO *n*=12	CH *n*=8	CB *n*=4
SOLULM	1994	1.2 *0.9*	0.6 *0.8*	1.1 *0.6*	1.8 *1.2*	1.4 *0.5*
	1995	2.9 *2.6*	0.7 *0.9*	2.1 *1.9*	5.4 *2.5*	4.6 *2.0*
	Change	+1.7	+0.1	+1.0	+3.6	+3.2
VERTHA	1994	0.0 *0.0*	0.0 *0.0*	0.0 *0.0*	0.0 *0.0*	0.0 *0.0*
	1995	0.5 *1.9*	0.0 *0.0*	0.0 *0.0*	0.6 *1.2*	2.7 *5.0*
	Change	+0.5	0.0	0.0	+0.6	+2.7
Total prominent species cover	1994	4.6	2.4	4.8	5.3	5.3
	1995	12.7	4.5	9.3	19.0	26.1
	Change	+8.1	+2.1	+4.5	+13.7	+20.8
Total other species cover	1994	1.8	1.4	2.4	2.7	1.0
	1995	4.6	1.8	3.8	8.6	4.9
	Change	+2.8	+0.4	+1.4	+5.9	+3.9
Total species cover	1994	6.4	3.8	7.2	8.0	6.3
	1995	17.3	6.3	13.1	27.6	31.0
	Change	+10.9	+2.5	+5.9	+19.6	+24.7
Total number of species (*S*)	1994	66	37	53	48	25
	1995	94	43	60	74	52
	change	+28	+6	+7	+26	+27

Appendix 35. Occurrence and change in cover for glade herbaceous species from 1994 to 1995. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Abbreviations are defined in Appendix 4. Non-native and state listed species are noted. ++ = present/ increasing, += = present/ no change, +- = present/ decreasing, +0 = present/ decreasing to zero, 0+ = increasing from zero, 00 = absent both years, and * = cover present at <0.05%.

Species	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
ACAGRA	++	+-	+=	++	++
AGATEN	+*+	0+	+*+	++	0+
AGRPER	++	00	00	00	++
AGRPUB	+*=	+*=	00	00	00
AGRROS	+*+	+*=	+*+	+*=	+0
ALLSTE	+-	00	00	+-	00
AMBART	+*0	+*0	00	00	00
ANEVIR	+*+	++	00	0+*	00
ARILON	++	00	++	++	++
ASCVER	+*=	00	00	+*=	00
ASCVIR	+*=	00	+*+	00	00
ASPPLA	+-*	00	+-*	+*0	+-*
ASTANO	+*+	+*+	+*=	00	+*+
ASTOBL	++	+-	+-	++	++
ASTPAT	+*=	+*=	00	00	0+*
BOUCUR	++	+-	++	++	++
BRIEUP	++	+=	+*+	+*+	++
BROCOM[x]	+*+	00	+*=	++	+*+
BROPUB	+=	+-	+*+	00	00
CARSPP	+=	00	+=	++	++
CASFAS	++	++	++	++	++
CHAMAC	+*0	00	00	00	+*0
CHEALB	0+*	00	00	0+*	00
CROMON	++	+=	+=	++	++
CUNORI	+*=	+*=	0+*	00	0+*
DALCAN	+=	+*+	+=	+-*	+*=
DESGLA	0+*	00	00	00	0+
DESGLU	+*=	+*0	+=	00	00
DESPAN	0+*	0+*	00	00	00
DICACU	++	+-	++	++	++
DICBOS	0+*	0+*	00	0+	00
DIGISC[x]	+*0	+*0	00	00	00
ELYVIR	++	0+*	+=	+*+	++

Appendix 35 (cont.).

Species	Overall n=16	CN n=4	BO n=4	CH n=4	CB n=4
ERACAP	0+*	00	00	00	0+*
ERASPE	++	0+	0+	++	+*+
ERIANN	+*0	+0	00	00	00
EUPALT	+*+	0+	+*+	00	00
EUPCOR	0+	0+*	0+	00	00
FESOBT	+*=	0+*	+*=	00	0+*
GALCIR	+=	+-	+*+	+*=	+0
GALPIL	+*=	00	+=	00	+*=
GALREG	+=	+*-	++	+-	+-
GEUCAN	+=	+-	++	+=	+*0
GLACAN	++	+-*	+-	+=	++
HELDIV	++	+-	++	++	++
LACCAN	+*=	+-*	00	0+*	00
LESCAP	+*+	00	00	0+	+*=
LESVIR	+*=	+*=	00	00	+*0
LEUMUL	0+*	00	00	00	0+*
MANVIR	+=	+-	++	+-	00
MONBRA	++	+=	++	+*+	+=
MUHSOB	++	++	00	++	++
OPUHUM	+*=	00	+*=	+-	00
OXADIL	+*=	00	00	+*=	+*+
PANFLE	+*+	00	00	++	0+
PASLUT	+*=	+*0	00	00	0+*
PELATR	+-*	+-	00	00	+*0
PENPAL	+-	+-*	+-	+=	+=
PHRLEP	0+*	00	0+*	00'	00
POAPRA[x]	+*=	00	+*+	00	00
POASP.[x]	+-*	00	00	+-	00
POIDEN	+-	+=	+=	+-*	+-
POLTEN	+*0	00	00	00	+*0
RATPIN	+*0	+*0	00	00	00
ROSCAR[w]	+*+	00	00	++	+=
ROSMUL[x,w]	+*0	00	00	00	+*0
RUBENS[w]	+=	00	++	00	00
RUDMIS[e]	++	00	00	++	00

Appendix 35 (cont.).

Species		Overall n=16	CN n=4	BO n=4	CH n=4	CB n=4
RUEHUM		++	++	+=	00	++
SANCAN		+•=	+•+	0+•	+•=	+•0
SCHSCO		++	++	++	++	+=
SENPLA		+=	+-	+•+	+•=	+-
SETFAB[x]		0+	00	00	0+•	0+
SETVIR[x]		+•=	+•0	00	00	+•+
SISALB		+•=	00	+•=	00	00
SMIHIS[w]		0+•	0+•	00	00	00
SOLRAD		+-•	+-•	00	00	+-•
SOLULM		++	++	++	++	++
SPOVAG		++	+•0	+=	++	00
STYBIF		+•=	00	+•=	00	00
SYMORB[w]		+•0	00	00	00	+•0
TRIBRA		+•+	+0	00	++	0+•
TRIFLA		++	+-	++	++	++
VERTHA[x]		0+•	00	00	00	0+•
VERURT		0+•	00	00	0+•	00
Total number of species (S)	1994	73	44	42	41	44
	1995	77	44	47	47	46

[x] Exotic.

[e] Endangered in Illinois.

[w] Should have been recorded and analyzed with woody vegetation.

Appendix 36. Mean cover for prominent glade herbaceous species and change with treatment. Treatments are control (CN), burn (BO), cut-herbicide (CH), and cut-burn (CB). Standard deviations are in italics. Abbreviations are defined in Appendix 4. * = cover present at <0.05%. Change associated with * values is reported to the nearest 0.1%.

		Cover (%)				
Species	Year/Change	Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
ARILON	1994	0.3	0.0	0.3	0.7	0.1
		0.5	*0.0*	*0.5*	*0.7*	*0.1*
	1995	0.6	0.0	0.5	1.8	0.3
		0.9	*0.0*	*0.8*	*1.0*	*0.5*
	Change	+0.3	0.0	+0.2	+1.1	+0.2
ASTOBL	1994	1.8	1.0	1.2	4.3	0.9
		1.8	*1.0*	*1.4*	*1.3*	*0.8*
	1995	3.2	0.5	1.1	8.1	3.0
		3.8	*0.6*	*1.3*	*3.1*	*3.8*
	Change	+1.4	-0.5	-0.1	+3.8	+2.1
BOUCUR	1994	1.9	1.0	2.6	3.4	0.7
		2.3	*1.0*	*4.2*	*1.2*	*0.8*
	1995	3.1	0.9	4.5	6.0	1.1
		4.4	*1.3*	*7.6*	*3.0*	*1.3*
	Change	+1.2	-0.1	+1.9	+2.6	+0.4
CASFAS	1994	0.1	0.1	0.1	0.1	0.1
		0.1	*0.1*	*0.1*	*0.2*	*0.1*
	1995	1.1	0.5	1.1	1.0	2.0
		1.6	*0.7*	*1.0*	*0.7*	*3.1*
	Change	+1.0	+0.4	+1.0	+0.9	+1.9
CROMON	1994	0.3	0.2	0.2	0.5	0.1
		0.3	*0.2*	*0.2*	*0.4*	*0.2*
	1995	0.8	0.2	0.2	2.0	0.9
		1.3	*0.2*	*0.2*	*2.2*	*1.0*
	Change	+0.5	0.0	0.0	+1.5	+0.8
DICACU	1994	1.2	0.2	1.5	1.3	1.7
		1.1	*0.2*	*0.9*	*1.3*	*1.4*
	1995	2.6	0.1	2.8	3.6	4.0
		2.8	*0.1*	*1.6*	*4.1*	*2.6*
	Change	+1.4	-0.1	+1.3	+2.3	+2.3
HELDIV	1994	1.6	1.3	0.7	1.4	2.9
		1.5	*1.0*	*1.0*	*1.6*	*1.7*
	1995	3.1	1.2	2.2	1.9	7.2
		3.3	*1.0*	*3.5*	*2.2*	*2.5*
	Change	+1.5	-0.1	+1.5	+0.5	+4.3

Appendix 36 (cont.).

Species	Year/Change	Cover (%) Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
MUHSOB	1994	0.2	0.4	0.0	0.3	0.3
		0.4	*0.5*	*0.0*	*0.5*	*0.2*
	1995	0.8	0.6	0.0	0.8	2.1
		1.4	*0.5*	0.0	*1.2*	*2.4*
	Change	+0.6	+0.2	0.0	+0.5	+1.8
RUDMIS	1994	0.2	0.0	0.0	0.9	0.0
		1.0	*0.0*	*0.0*	*1.8*	*0.0*
	1995	0.3	0.0	0.0	1.2	0.0
		1.1	*0.0*	*0.0*	2.2	*0.0*
	Change	+0.1	0.0	0.0	+0.3	0.0
RUEHUM	1994	0.4	0.6	0.2	0.0	0.8
		0.8	*0.7*	*0.2*	*0.0*	*1.4*
	1995	0.6	0.7	0.2	0.0	1.6
		1.3	*0.9*	*0.2*	*0.0*	*2.4*
	Change	+0.2	+0.1	0.0	0.0	+0.8
SCHSCO	1994	1.8	1.4	1.9	1.9	1.8
		1.8	*2.0*	*2.0*	*1.8*	*2.3*
	1995	2.1	1.5	2.7	2.2	1.8
		2.5	*2.6*	*3.4*	*2.3*	*2.6*
	Change	+0.3	+0.1	+0.8	+0.3	0.0
SOLULM	1994	0.4	0.4	0.6	0.1	0.4
		0.5	*0.3*	*0.6*	*0.1*	*0.6*
	1995	0.6	0.5	0.7	0.7	0.7
		0.5	*0.3*	*0.6*	*0.5*	*0.7*
	Change	+0.2	+0.1	+0.1	+0.6	+0.3
SPOVAG	1994	0.2	*	0.6	0.1	0.0
		0.6		*1.2*	*1.6*	*0.0*
	1995	0.5	0.0	0.6	1.5	0.0
		1.4	*0.0*	*1.2*	*2.5*	*0.0*
	Change	+0.3	-0.0	0.0	+1.4	0.0
TRIFLA	1994	0.7	0.6	0.3	1.3	0.5
		0.8	*0.5*	*0.5*	*1.5*	*0.3*
	1995	1.6	0.3	0.4	3.5	2.1
		2.0	*0.2*	*0.6*	*2.9*	*1.3*
	Change	+0.9	-0.3	+0.1	+2.2	+1.6

Appendix 36 (cont.).

Species	Year/Change	Cover (%) Overall *n*=16	CN *n*=4	BO *n*=4	CH *n*=4	CB *n*=4
Total prominent species cover	1994	11.1	7.2	10.2	16.3	10.3
	1995	21.0	7.0	17.0	34.3	26.8
	Change	+9.9	-0.2	+6.8	+18.0	+16.5
Others	1994	3.4	4.1	2.8	3.8	3.4
	1995	5.4	3.2	4.7	5.9	6.8
	Change	+2.0	-0.9	+1.9	+2.1	+3.4
Total species cover	1994	14.5	11.3	13.0	20.1	13.7
	1995	26.4	10.2	21.7	40.2	33.6
	Change	+11.9	-1.1	+8.7	+20.1	+19.9
Total number of species (*S*)	1994	73	44	42	41	44
	1995	77	44	47	47	46
	Change	+4	0	+5	+6	+2

Appendix 37. Descriptive statistics for age of woody ingrowth within the barrens.

Group/species (number aged)	Mean	Std	Min	Max
All species (46)	37.0	10.2	23	84
Hardwoods (36)	36.6	3.5	28	41
Juniperus virginiana (10)	38.1	20.1	23	84
Hardwoods by species:				
Acer saccharum (5)	36.6	2.4	34	40
Carya texana (5)	36.0	3.9	31	40
Cercis canadensis (2)	35.7	6.1	29	41
Fraxinus americana (12)	36.5	4.1	28	40
Quercus prinoides (11)	37.2	3.0	32	40
Quercus rubra (1)	39.0		39	39

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