RESEARCH ARTICLE

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# An Evaluation of Oak Woodland Management in Northeastern Illinois, USA

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**ABSTRACT:** We examined vegetation change over time at managed and unmanaged oak woodland sites located in Cook County, Illinois, forest preserves. The managed site (Cap Sauers Holding) was dominated by red and white oak *(Quercus rubra* and *Q. alba)* in 1995, and density was 313 trees ha-'. Historical records indicate that white oak dominated the site and tree density was between 5 and 50 trees ha-'. Management initiated in 1989 included prescribed burning and woody plant removal. Vegetation was surveyed in 1988 and 1995. No significant change in total ground cover or in cover of native or exotic species (plants <1 m tall) was detected in 1995. However, herbaceous species as a percent of the total ground cover increased from 58% in 1988 to 81% in 1995. Woody species decreased from 42% of the total cover in 1988 to only 19% in 1995. Selected taxa—white snakeroot *(Eupatorium rugosum),* enchanter's nightshade *(Circaea lutetiana),* woodland knotweed *(Polygonum virginianum),* and oak species *(Quercus* spp.)—significantly increased in cover between the 1988 and 1995 surveys. Exotic shrubs decreased by 3139 stems ha$^{-1}$, natives decreased by 2635 stems ha-', and the canopy cover of exotic and native shrubs decreased significantly. Tree canopy cover at the managed site did not change significantly between years. In contrast, at the unmanaged site (McClaughry Springs Forest Preserve), total ground cover (plants <1.4 m tall) significantly increased over four years, mostly due to increases in woody vegetation. Density of woody species in all size classes increased, and there was a significant increase in Virginia creeper *(Parthenocissus quinquefolia).* Invasive shrubs substantially increased in the suppressed (stems <1.4 m tall) and intermediate (stems >1.4 m tall but <11 cm dbh) layers. Management at Cap Sauers Holding, while not having a conclusive positive effect on herbaceous species, has substantially reduced the density and cover of invasive and exotic shrubs and maintained tree canopy cover, all of which increased at the unmanaged site. The results of this study indicate that management, in the form of prescribed burns and removal of woody species, achieved some restoration goals at this site.

*Index terms:* ground-layer vegetation, oak woodland, prescribed burning, restoration, vegetation change

## INTRODUCTION

In 1820 forested ecosystems dominated by oak *(Quercus* spp.) covered 40–45% (5.6 million ha) of Illinois, mostly along river valleys and steep slopes. Today about 1.7 million ha, or 31%, of that area remain in forest (Anderson 1991, Illinois Department of Energy and Natural Resources 1994). Factors influencing the distribution and character of Illinois forests since European settlement include fire suppression, deforestation, effects of herbivores, and exotic species invasion. With European settlement fires were suppressed, allowing woody species to invade grasslands and leading to the conversion of savannas and woodlands to closed forests (Gleason 1922, Curtis 1959). Between 1820 and 1980, nearly 4 million ha of forested land in Illinois were converted to agriculture and about 203,000 ha were converted to urban areas (Illinois Department of Energy and Natural Resources 1994). Livestock grazing degraded natural communities, changing the character of many savannas (White 1978); and in the later twentieth century, the white-tailed deer *(Odocoileus virginianus),* a native herbivore, has become a threat to natural areas in the eastern United States (Anderson and Loucks 1979, Alverson et al. 1988, Anderson 1997). Further degradation of forests has occurred as a result of exotic species invading fragmented or degraded areas and competing with native forest-understory species (White 1978, McCune and Cottam 1985, Patterson 1992, Illinois Department of Energy and Natural Resources 1994). Some of the most troubling species are woody shrubs (Illinois Department of Energy and Natural Resources 1994, Schwegman 1994).

### Restoration Activities

To counteract or prevent further forest degradation caused by historic and con-

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temporary factors, many forested areas are now being managed or restored (Patterson 1992). Restoration goals include protecting and preserving the native flora and fauna, returning sites to historic conditions, and reestablishing ecosystem functions such as habitat structure and water-shed protection (Packard 1993, Jackson et al. 1995, Stevens 1995).

Restorationists often seek to achieve their goals by reintroducing native processes such as fire into degraded ecosystems. Fire is thought to be an effective management tool to restore forests to historic conditions. It causes a decrease in tree canopy cover and in the number of woody species and a change in herbaceous species composition and abundance (Anderson and Brown 1986, Tester 1989, Anderson and Schwegman 1991). Reducing canopy cover increases the amount of light reaching the forest floor, which favors the reproduction of shade-intolerant oaks (Curtis 1959, Abrams 1992). Absence of fire in a fire-adapted ecosystem causes species assemblages to shift toward greater numbers of shade-tolerant, mesic forest species (Abrams 1992). Fire controls excessive woody growth as well as growth of some exotic species, which often are not adapted to burning (Anderson and Schwegman 1991, Nuzzo 1991). At some restoration sites, degraded ground-layer vegetation is being enhanced through the sowing of seeds of native woodland herbs (Packard 1997). Exotic shrubs are often cut and removed, and the invasive herbaceous species garlic mustard *(Alliaria petiolata) is* hand-pulled (Schwegman 1994). (Vascular plant nomenclature follows Swink and Wilhelm [19941.)

### Rationale and Goals for the Study

We used monitoring data and statistical methods to evaluate management in a woodland located in a Cook County Forest Preserve in northeastern Illinois (Cap Sauers Holding, Figure 1: CSH). The site was surveyed in 1988, management of the study area began in 1989, and we resurveyed the vegetation in 1995. All monitored areas at the managed site were treated. For comparison to Cap Sauers Holding, we examined vegetation change at a nearby unmanaged site (McClaughry Springs Forest Preserve, Figure 1: McCS), which had been surveyed in 1991-92.

The forest preserve district's stated management goal for the Cap Sauers Holding site was "to reestablish native vegetation." We subdivided that goal into three objectives for which specific predictions could be made to assess progress toward the overall goal. The objectives are to improve the quality of the native ground-layer vegetation, control woody vegetation (especially exotic shrubs), and increase the amount of light reaching the understory, as measured by a reduction in tree canopy cover. We predicted that successful management would lead to the following changes: (1) increase in richness and cover of native species; (2) decrease in richness and cover of exotic species; (3) decrease in density and cover of shrubs, especially exotic shrubs; (4) decrease in total tree canopy cover; and (5) increase in oak seedling cover. We compared vegetation change between sampling times for each site. Then we compared the direction of change at the managed site to the direction of change at the unmanaged site. We evaluated change in the context of achieving the objectives outlined above.

## METHODS

### Managed Study Site--Cap Sauers Holding Forest Preserve

#### *Site Description*

Cap Sauers Holding is a 615-ha forest preserve in Cook County, Illinois, encompassing a variety of natural communities including wetland, prairie, savanna, and forest. We studied a wooded area on rolling topography in the western portion of the preserve. Government Land Office (GLO) surveys from 1821 suggest that the study area, in Section 19 of Palos Township, was savanna with a density of 5—50 trees ha-' (Nyberg and Nyberg 1993). Level land immediately southwest of the study area was prairie. Of the nineteen witness trees recorded in the survey for Section 19, seventeen were white oak *(Quercus alba);* there were single trees of black oak *(Quercus velutina)* and black walnut *(Juglans nigra)* (Nyberg and Nyberg 1993).

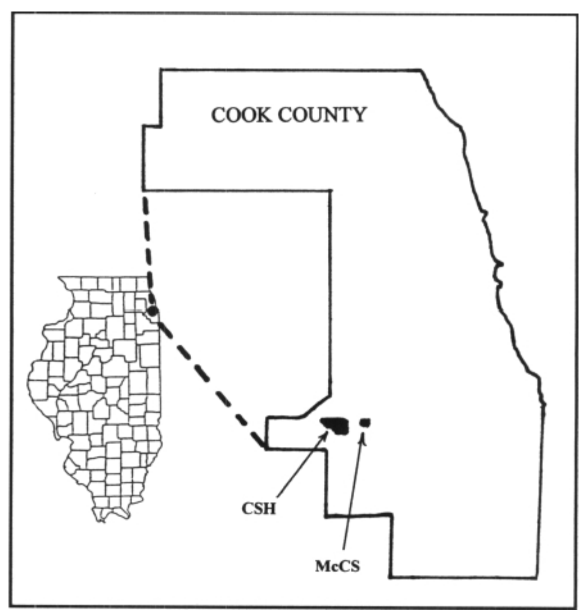

**Figure 1. Location of Cap Sauers Holding (CSH) and McClaughry Springs (McCS) Forest Preserves in Cook County, Illinois, USA.**

#### *Management*

The Cook County Forest Preserve District's management goal is to "reestablish native vegetation." Management practices include periodic prescribed burns, cutting and removing stems of invasive woody shrubs, removing exotic species, and sowing small amounts of seed of some forest herbs (seeding information available in Laatsch [1997]). Prescribed burns were applied to the site at irregular intervals, with no area being burned more frequently than every two years. The season of the burn (fall or spring) was held constant for each area. Ninety percent of the study transects' total length lies in spring-burned areas and the remainder lies in fall-burned areas. Fifty percent was burned once in seven years. The remaining areas were burned either two or four times in seven years.

### *Vegetation Surveys*

Vegetation was surveyed in July 1988 and July 1995 along four permanent monitoring transects with a combined length of 1200 m. Data were collected on ground cover plants (all vegetation < 1 m tall), shrubs (woody plants 0)1 m tall and < 5.1 cm dbh), and trees (woody plants 0)5.1 cm dbh) (Apfelbaum 1989).

We estimated percent ground cover of each species in 1-m' quadrats using cover categories modified from Daubenmire (1959): (1) 0-2%, (2) 2-20%, (3) 20-50%, (4) 50-80%, (5) 80-100%. A total of 120 quad-rats were sampled in each year. Shrub density was estimated by counting stems of each species in a 1-m-wide belt transect. Tree density and basal area were estimated by counting and measuring the dbh of stems by species in a 2-m-wide belt transect. Shrub and tree canopy cover were estimated to the nearest centimeter and summarized as meters of intercept of each species directly over the transect. Belt transect and line intercept surveys were completed in 50-m sections of transect and data were analyzed using each 50-m section as a sample unit.

### Statistical *Analyses*

Due to the large numbers of species and zeroes in the data set, data were pooled into more inclusive variables: native, exotic, woody and herbaceous ground covers; densities and canopy covers of native and exotic shrubs; total tree canopy cover; and oak, non-oak, and exotic tree species canopy covers. In addition, for ground cover it was necessary to pool data from three consecutive 1-m$^2$ quadrats to normalize the data set. Data were transformed to achieve normality when necessary, and were analyzed for differences between years and the random effect of transect with two-way (year and transect as fixed and random effects, respectively) analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) using the SAS GLM procedure (SAS Institute 1989). When the results of MANOVA were significant, pooled variables were tested individually using a protected ANOVA (Scheiner 1993). Pillai's trace was the test statistic used to interpret MANOVA results. MANOVA and ANOVA tables are available in Laatsch (1997). Tree density and basal area were calculated from belt transect data collected in 1995. Importance values for tree species were calculated as (relative density + relative dominance)/2 (Adams and Anderson 1980).

The Wilcoxon nonparametric test (corrected for multiple tests using Bonferroni procedure [Sokal and Rohlf 19951) was used to test individual species for differences between years. Species occurring most frequently in quadrats were chosen for testing. Oak was also included to test the prediction regarding cover of oak seedlings. The SAS NPAR1WAY procedure was used to perform nonparametric tests (SAS Institute 1989). Significance was accepted at $P < 0.05$ for all tests unless otherwise indicated. Since the treatment at the managed site is not replicated, statistical interpretation relative to the study area may not be more broadly applicable.

## Unmanaged Study Site—McClaughry Springs Forest Preserve

### Site *Description*

McClaughry Springs, an 80-ha Cook County forest preserve is located 3.2 km east of the Cap Sauers Holding study site. The study site is wooded and on level upland surrounded by steep slopes. Historic tree density at the site (also derived from the 1821 GLO surveys) was < 125 trees ha$^{-1}$. As at Cap Sauers Holding, the majority of witness trees for this section (10 out of 12) were white oak (Nyberg and Nyberg 1993). No prescribed burning or removal of woody or exotic vegetation had been conducted in the study area as of the 1995 survey.

### *Vegetation Surveys*

Ground-layer vegetation was surveyed in June or July 1991 and July 1995, and woody vegetation was surveyed in July 1992 and July 1995. Surveys employed two permanent transects, each 325 m in length. Percent ground cover for each species < 1.4 m tall was estimated in 0.25-m$^2$ quadrats using stratified random sampling at 10-m intervals for 150 feet of the transect. Fifteen quadrats were sampled on each transect for a total of 30 quadrats. Woody vegetation was surveyed at 25-m intervals using the point-quarter method for three size classes: suppressed, intermediate, and dominant. Suppressed vegetation includes woody stems less than breast height (< 1.4 m tall), intermediate vegetation includes small trees greater than breast height, but not reaching the uppermost canopy layer (in general < 11 cm dbh). Dominants are trees reaching the upper canopy (in general stems ®11 cm dbh). Thirteen points were sampled on each transect for a total of 26 sampling points.

### *Statistical* Analyses

Total ground cover was analyzed for differences between years with a nonparametric Wilcoxon test using SAS NPAR1WAY procedure (SAS Institute 1989). Wilcoxon tests were also used to test for differences between years for native and exotic, and woody and herbaceous species groups, and for Virginia creeper *(Parthenocissus quinquefolia),* gray dogwood *(Cornus racemosa),* and false Solomon's seal *(Smilacina racemosa).*

Total density of suppressed vegetation, and total density and basal area of intermediate and dominant vegetation, were calculated from point-quarter data. In addition, density of individual suppressed species, and density and basal area of intermediate and dominant woody species were calculated. For the dominant class, importance values were calculated as (relative density + relative dominance)/2.

We tested for changes in woody species abundance (changes in the relative proportions of species) using a contingency Chi-square test. Density by species was used to test suppressed vegetation for changes between 1992 and 1995. Basal area by species was used to test for changes in abundance of intermediate and dominant species during this time period.

## RESULTS

### Cap Sauers Holding Forest Preserve

*Ground Cover Vegetation*

Species richness in the ground layer of the managed site increased between the two survey years. Eighty species were recorded in 1988 and 98 species were recorded in 1995, an increase of 18 species. In 1988, 67 species were native and 13 were exotic, and in 1995, 87 species were native and 11 were exotic. Abundant exotic species in this layer in 1995 were glossy buckthorn *(Rhamnus frangula),* creeping smartweed *(Polygonum cespitosum* var. *longisetum),* and Spanish needles *(Bidens bipinnata)* with 3.4% cover, 3.1% cover, and 2.8% cover, respectively. Of the 80 species recorded in 1988, 52 were herbaceous species and 28 were woody species, while in 1995, 77 of the 98 species were herbaceous and 21 were woody. The species present were primarily woodland species common to the Chicago region.

Total ground cover did not change significantly from 1988 to 1995 (ANOVA, F=0.05, df=1,66, P=0.8244); it was 49.6±3.2% (mean ± SE) and 48.6±3.2% for each year, respectively. Pooled cover of native and exotic species was also unaffected by year (MANOVA, F=0.733, df =2,2, P=0.577). Native species had approximately 40% cover or about four times the percent cover of exotic species in both years. Cover of pooled woody species decreased from 20.8±1.9% to 9.6±1.9% between 1988 and 1995, and pooled cover of herbaceous species increased from 28.9±2.8% to 40.3±2.8%; but these changes were not significant (MANOVA, F=6.6738, df=2,2, P=0.1303) (Table 1). However the proportion of herbaceous to woody species changed significantly ($c^2$=30.19, df=1, P<0.001). In 1988 herbaceous species comprised 58.1% of the ground cover while woody species comprised 41.9%. In 1995 herbaceous species comprised 80.8% of the ground cover and woody species comprised 19.2%. Nonparametric Wilcoxon tests showed significant increases in ground cover between 1988 and 1995 for enchanter's nightshade *(Circaea lutetiana),* white snakeroot *(Eupatorium rugosum),* woodland knotweed *(Polygonum virginianum),* and oak. Black snakeroot *(Sanicula gregaria)* declined significantly; glossy buckthorn did not change significantly (P>0.10) (Table 1). Observed trends in species cover that we did not test statistically were increases in creeping smartweed, Spanish needles, and white grass *(Leersia virginica),* and decreases in poison ivy *(Rhus radicans),* Virginia creeper, and gray dogwood. Frequency and cover of all ground-layer species in each year are listed in Laatsch (1997). Litter cover was estimated at 79% in 1988 and 82% in 1995. Percent of ground without vegetative cover was 53% in 1995.

**Table 1. Percent ground cover (mean ± 1 SE) of species groups and selected ground layer species at Cap Sauers Holding in 1988 and 1995.**

| | N | 1988 | 1995 |
|---|---|---|---|
| SPECIES GROUPS | | | |
| Native[a] | 74 | 42.8 ± 2.8 | 38.5 ± 2.8 |
| Exotic [b] | 74 | 6.8 ± 1.6 | 10.1 ± 1.6 |
| Woody | 74 | 20.8 ± 1.9 | 9.6 ± 1.9 |
| Herbaceous | 74 | 28.9 ± 2.8 | 40.3 ± 2.8 |
| Total cover ° | 120 | 49.6 ± 3.2 | 48.6 ± 3.2 |
| SELECTED SPECIES[d] | | | |
| *Eupatorium rugosum* | 120 | 0.6 ± 0.2 | **8.0 ± 1.0 |
| *Rhamnus frangula* | 120 | 2.6 ± 0.9 | 3.3 ± 0.9 |
| *Circaea lutetiana* | 120 | 2.4 ± 0.5 | **2.8 ± 0.4 |
| *Quercus* spp. | 120 | 0.1 ± 0.0 | **0.4 ± 0.1 |
| *Polygonum virginianum* | 120 | 3.3 ± 0.7 | **3.5 ± 0.7 |
| *Sanicula gregaria* | 120 | 13.1 ± 2.0 | **1.1 ± 0.3 |

[a] Data were transformed as the arcsin of the square root of the proportion (P<W: 0.1640).
[b] Data were transformed as the log of the proportion (P<W: 0.0553).
[c] Total cover is the sum of cover values for all species.
[d] Significance is indicated by asterisk (** P<0.01). Critical values were adjusted with Bonferroni correction (e.g., 0.05/6=0.008).

*Shrub Layer*

In 1988, 25 shrub layer species were recorded including 6 exotic species; there were 7 species of shrubs, 4 vines, and 14 tree species. In 1995, 27 shrub layer species were sampled of which 7 were exotic; there were 11 shrubs, 3 vines, and 13 species of trees.

Shrub density declined significantly over time. This decline was significant at the 10% level (MANOVA, F=16.0154, df=2,2, P=0.0588). Because the P-value for the MANOVA was close to the 0.05 level, we proceeded with protected ANOVA for each of the response variables. There was a significant decline for pooled native species (ANOVA, F=32.65 df=1,40, P=0.0001) and pooled exotic species (ANOVA, F=60.48 df=1,40, P=0.0001) (Table 2). Standardized canonical coefficients showed that the decline in exotic species (1.67) was more responsible for the significant difference between years in shrub density than was the decline in native species (0.25). Exotic species de-creased by 3139 stems ha-' and natives decreased by 2635 stems ha-' between the two samples. Species with significant de-clines in stem density, according to Wilcoxon tests, were two exotic shrubs, glossy buckthorn and arrow-wood *(Viburnum dentatum),* and gray dogwood, a native shrub. Other species that increased or decreased between samples, but were not tested statistically, are listed in Table 2.

Table 2. Shrub density in stems/ha (mean ± 1 SE) for selected woody species in 1988 and 1995 at Cap Sauers Holding. Species are grouped based on whether a decrease, maintenance, or increase of density was observed between the two years.

| Species | 1988 | 1995 | P-value[b] |
|---|---|---|---|
| DECREASING | | | |
| *Rhamnus frangula*[a] | 3208 ± 494 | 758 ± 573 | *(0.0001) |
| *Cornus racemosa*[a] | 1067 ± 292 | 17 ± 17 | *(0.0001) |
| *Viburnum dentatum*[a] | 867 ± 338 | 267 ± 158 | *(0.0064) |
| *Crataegus* spp.[a] | 567 ± 155 | 200 ± 58 | (0.1263) |
| *Prunus serotina* | 483 ± 148 | 83 ± 30 | |
| *Rhamnus cathartica* | 292 ± 105 | 33 ± 20 | |
| *Prunus virginiana* | 208 ± 71 | 17 ± 17 | |
| *Fraxinus americana* | 142 ± 76 | 50 ± 35 | |
| *Corylus americana* | 142 ± *100* | *0 ± 0* | |
| *Fraxinus pennsylvanica* | 83 ± 38 | *0 ± 0* | |
| *Rhus radicans* | 58 ± 31 | 17 ± 17 | |
| *Carya ovata* | 50 ± 37 | 8 ± 9 | |
| UNCHANGED | | | |
| ***Quercus rubra*** | 42 ± 21 | 42 ± 21 | |
| INCREASING | | | |
| ***Rubus allegheniensis*** | 0 ± 0 | 283 ± 247 | |
| *Rosa multiflora* | 8 ± 9 | 242 ± 207 | |
| *Vitis* spp. | 42 ± 35 | 79 ± 68 | |
| SPECIES GROUPS | | | |
| Native | 3418 ± 357 | 783 ± 357 | |
| Exotic | 4288 ± 642 | 1149 ± 642 | |

[a] These species were tested for significant changes between years using the Wilcoxon test. Significant changes are marked with *.

[b] Four tests were performed so significance was accepted at P < 0.05/4, or 0.0125.

### Tree Layer

In 1995 tree density was 165 and 313 trees ha-' for trees >25 cm dbh and >10 cm dbh, respectively. Twenty-two species were recorded in the tree layer during the study. All of these are native except for apple *(Malus* spp.), glossy buckthorn, and common buckthorn *(Rhamnus cathartica).* Species with the highest importance values in 1995 were red oak *(Quercus rubra)* and white oak followed by black cherry *(Prunus serotina)* and bur oak *(Quercus macrocarpa),* respectively (Table 3). The density of dead black oak stems (17.4 trees ha-') was higher than that of live stems (4.4 trees ha-'). Basal area of trees >10 cm dbh was 32.5 $m^2$ ha-'.

Total tree canopy cover did not change significantly between years (ANOVA, F=0.53 df=1,40, P=0.4727). There was no difference between years for pooled oak, non-oak native, and exotic species groups (MANOVA, F=3.7466, df=3,1, P=0.3589). Oaks dominated the canopy in 1995 with 83.5±6.3% cover, nearly four times that of non-oak natives (19.4±3.6%) and exotics (2.3±1.3%) combined. Red oak had greater canopy cover than white oak in both survey years. Oak species, including white, red, bur, and black oak, decreased slightly between samples while non-oak natives, including black cherry, hawthorn *(Crataegus* spp.), American elm *(Ulmus americana),* and shagbark hickory *(Carya ovata),* increased slightly.

## McClaughry Springs Forest Preserve

### Ground Cover Vegetation

Nineteen species were recorded at McClaughry Springs in 1991 and 30 in 1995; a total of 37 species over both years. Thirty species were native and seven were exotic. Of the total species for both years, 17 were herbaceous and 20 were woody. In 1991 and 1995, 8 out of 10 of the most abundant ground cover species were woody, and woody species had seven to eight times the cover of herbaceous species in both years. Percent cover of native species was about ten times the cover of exotics in both years (Table 4).

Wilcoxon tests showed significant increases in total ground cover at McClaughry Springs as well as significant increases for woody and herbaceous species and native and exotic species (Table 4). Between the two samples, there was a large and significant increase in ground cover for Virginia creeper (P<0.001). Gray dogwood and false Solomon's seal showed no significant change and had less cover than Virginia creeper (Table 4).

### Woody Vegetation

A contingency chi-square test on density of suppressed woody vegetation showed a significant change in species relative abundance ($x^2$=[1]7788.57, df=7, P<0.001) between the two samples. Changes in density included an increase in Virginia creeper, the most abundant species. Poison ivy showed a large decrease, while arrow-wood *(Viburnum* spp.), gray dogwood, and buckthorn *(Rhamnus* spp.) all more than doubled in density from 1992 to 1995 (Table 5). Basal area of intermediate and dominant classes increased (Table 7). Chi-square tests on basal area of intermediate and dominant vegetation showed no significant change in relative proportions of species between years (dominant: $c^2$=2.54, df=7, P>0.9; intermediate: $c^2$=2.09, df=14, P>0.995). Density (stems/ha) of all three size classes increased (Tables 5, 6, and 7). Several tree taxa in the intermediate class—black cherry, ash *(Fraxinus americana* and *F. pennsylvanica),* and elm *(Ulmus rubra* and *U. americana)*—that had densities of

**Table 3. Density, relative density, basal area, relative dominance, and importance value (IV) for trees >10 cm dbh at Cap Sauers Holding in 1995, and average importance values for Wisconsin southern dry-mesic and dry forests (from Curtis 1959).**

| Species | Density (stems/ha) | Relative Density | Basal Area ($m^2$/ha) | Relative Dominance | IV[a] | IV dry-mesic[b] | IV dry[b] |
|---|---|---|---|---|---|---|---|
| *Quercus rubra* | 117.4 | *37.0* | 13.2 | 41.0 | *39.0* | 34.7 | *7.2* |
| *Quercus alba* | *65.2* | 21.9 | 14.5 | 45.1 | *33.5* | 17.4 | *26.7* |
| *Prunus serotina* | 21.7 | *6.8* | *0.7* | 2.1 | *4.5* | 1.9 | *7.7* |
| *Quercus macrocarpa* | 13.0 | *4.1* | *0.9* | *2.7* | 3.4 | 0.8 | *8.5* |
| *Ulmus rubra* | *13.0* | 4.1 | *0.3* | *0.9* | *2.5* | *5.7* | 1.3 |
| *Crataegus* spp. | 13.0 | 4.1 | *0.2* | *0.5* | *2.3* | - | - |
| *Rhamnus cathartica* | 13.0 | 4.1 | *0.4* | 1.2 | *2.7* | | |
| *Fraxinus americana* | *8.7* | *2.7* | *0.6* | 1.7 | *2.2* | *3.8* | *0.4* |
| *Tilia americana* | *8.7* | *2.7* | *0.3* | *0.8* | 1.8 | *9.5* | *0.3* |
| *Carya cordiformis* | *8.7* | *2.7* | *0.2* | *0.6* | 1.7 | 1.5 | *0.7* |
| *Carya ovata* | *8.7* | *2.7* | 0.1 | *0.3* | *1.5* | *2.8* | *2.7* |
| *Quercus velutina* | 4.4 | 1.4 | *0.5* | 1.7 | *1.5* | 1.8 | *32.7* |
| *Juglans nigra* | 4.4 | 1.4 | *0.3* | *0.9* | 1.1 | 1.1 | *0.9* |
| *Rhamnus frangula* | 4.4 | 1.4 | 0.1 | *0.3* | *0.8* | - | - |
| *Ulmus americana* | *4.4* | *1.4* | 0.1 | *0.2* | *0.8* | 1.3 | 1.2 |
| *Acer negundo* | 4.4 | 1.4 | 0.1 | *0.2* | *0.8* | <0.1 | *0.6* |
| *Acer saccharum* | | | | | | *7.6* | 0.1 |
| *Quercus ellipsoidalis* | | | | | | - | *3.5* |
| TOTALS | 313.1 | 100.0 | *32.5* | 100.0 | 100.0 | | |

[a] (relative density + relative dominance)/2.
[b] (relative frequency + relative density + relative dominance)/3.

about 400 stems ha$^{-1}$ in 1995 had approximately doubled their 1992 densities. Red oak, white oak, and Hill's oak *(Quercus ellipsoidalis)* were found at lower densities than black cherry, ash, and elm. For shrubs in this class, hawthorn had the highest density and much greater basal area than all other shrub and tree species in the intermediate size class. Shrub species in-creasing in density were hawthorn, arrow-wood, buckthorn, and honeysuckle *(Lonicera* spp.). These changes were not tested for significance (Table 6). In the dominant size class, white oak had the highest density and basal area in 1995, followed by red oak. White and red oak increased in density and basal area between the two samples; again this change was not tested for significance (Table 7). Density for trees >10 cm dbh was 275 trees ha$^{-1}$, which was lower than the 1995 density at Cap Sauers Holding.

## DISCUSSION

### Evaluation of Management

We predicted that with successful management, native species in the oak woodland would increase in richness and cover over time and exotic species would decrease, meeting the management objective of improving the quality of native ground-layer vegetation. The total number of species at the managed site increased between 1988 and 1995. Other studies have shown species richness to increase with prescribed burning in fire-dependent communities (Tester 1989, Anderson and Schwegman 1991, Mehlman 1992). However, in this study an increase in species richness was also observed at the unmanaged site.

The predicted increase in ground cover of native species was not observed at the managed site. At the unmanaged site, total ground cover increased, as did native and exotic species cover. Much of this increase however, was due to an increase in woody species, which composed >80% of the ground layer at this site in 1995. This site had fewer total species than the managed site, with several species overwhelmingly more abundant than all others. At the managed site, fire management probably was responsible for the decrease in woody species and the changes in abundance of some herbaceous species. Evidence for management positively affecting the ground layer is inconclusive. Species richness increased and proportions of native and exotic species cover remained the same at both sites.

A second management objective was to control woody understory vegetation, especially exotic shrubs. We predicted a decrease in shrub density and canopy cover with successful management. This management objective was met during the seven years of management at Cap Sauers Holding, as evidenced by changes in proportions of woody and herbaceous cover and changes in density and canopy cover of the shrub layer.

In the ground layer at Cap Sauers Holding, herbaceous species outnumbered woody species by about 3.5 to 1; this proportion of species numbers was maintained with the management regime. In terms of cover, woody species tended to decrease and herbaceous species tended to increase such that the proportions of woody to herbaceous species changed markedly. This is consistent with observed decreases in woody species after burning elsewhere (Anderson and Schwegman 1991). Some woody species in the ground layer, such as poison ivy, Virginia creeper, and gray dogwood, tended to decline as well.

Overall, glossy buckthorn showed no significant change in the ground layer. Nevertheless, glossy buckthorn decreased in all management zones except in one that had received two fall burns since 1988, where it increased. In addition, this zone had the smallest decrease for glossy buckthorn in the shrub class (>1 m and <5.1 cm

Table **4. Percent ground cover (mean** ± I SE) **for vegetation** <1.4 m in **height, at McClaughry Springs in 1991 and 1995. Data shown are for species groups and the three most abundant species at McClaughry Springs for the two survey years.**

| | N | 1991 | 1995 | P-value[b] |
|---|---|---|---|---|
| SPECIES GROUPS | | | | |
| Native | 30 | 32.6 ± 4.9 | 86.2 ± 6.4 | *(0.0001) |
| Exotic | 30 | 3.2 ± 2.0 | 8.9 ± 2.8 | *(0.0006) |
| Woody | 30 | 31.4 ± 4.4 | 83.2 ± 6.4 | *(0.0001) |
| Herbaceous | 30 | 4.4 ± 1.9 | 12.2 ± 3.7 | *(0.0027) |
| Total cover[a] | 30 | 35.9 ± 4.9 | 95.3 ± 6.9 | *(0.0001) |
| SELECTED SPECIES | | | | |
| *Parthenocissus quinquefolia*[c] | 30 | 14.2 ± 3.2 | 39.9 ± 1.9 | *(0.0001) |
| *Cornus racemosa* | 30 | 8.4 ± 3.2 | 10.7 ± 1.9 | (0.7780) |
| *Smilacina racemosa* | 30 | 4.0 ± 2.9 | 4.7 ± 3.3 | (0.2458) |

[a] Total cover is the sum of cover values for all species. The two years were compared using Wilcoxon tests. Five tests were performed so significance was accepted at P0.05/5 = 0.01.

[b] Significant changes are marked with *.

Three tests were performed; significance was accepted at P50.05/3 = 0.016666.

dbh) compared to the other zones. Fall (November) burns may be less successful than spring burns in controlling buckthorn.

The shrub layer declined overall at the managed site, with native and exotic species showing large declines in density and in canopy cover. Despite these decreases, exotic shrubs still had greater density than native shrubs after management. But in canopy cover, native shrubs surpassed exotic shrubs before and after management. Trends of increasing density and canopy cover in the shrub layer were seen only for species forming aggregations-common blackberry *(Rubus allegheniensis)* and multiflora rose *(Rosa multiflora),* and for vine species-Virginia creeper, poison ivy, and grape *(Vitis* spp.).

In contrast, at the unmanaged site, woody species in the ground and shrub layers tended to increase. For example, the suppressed layer at McClaughry Springs increased in density. Although this layer was dominated by vine and shrub species (especially Virginia creeper), some tree species were present, including ash, sugar maple *(Acer saccharum),* and elm. Since ash and elm also increased in density in the intermediate class, at least these species are apparently being recruited into the canopy. The increase in hawthorn, arrow-wood, buckthorn, and honeysuckle is the opposite of the pattern at the managed site where all of these species, excluding honeysuckle, showed significant declines. Buckthorn, despite having very low abundance at McClaughry Springs, increased in the suppressed and intermediate vegetation layers between 1992 and 1995.

Little is known about the historic shrub layer at these sites, thus it is difficult to decide composition, density, and canopy cover appropriate for a historically accurate restoration. However, John Walls, surveyor of Palos Township where both of these sites are located, mentioned the understory only once in the entire township. Since it is unlikely that shrubs were completely absent from this landscape, the fact that he only mentioned the understory once (in a floodplain thicket), may indicate that shrubs were present at low densities and did not impede passage through the woods (D. Nyberg, Department of Biological Scences, University of Illinois at Chicago, pers. corn.). Native shrubs may be an important component in this ecosystem, and though a site may benefit from control of their abundance, care should be taken not to remove them entirely from the community. For some sites, restoration of a native shrub component may be advisable (Whelan and Dilger 1992).

A third management objective was to increase the amount of light reaching the understory. We predicted that management progressing toward this goal would decrease tree canopy cover and increase frequency of oak seedlings, which are intolerant of shade (Curtis 1959). No increases or decreases were seen overall in tree canopy cover at Cap Sauers Holding, although it appears that canopy composition is shifting toward lower oak dominance. Although canopy cover of trees did not change significantly, the significant decrease in shrub cover should allow more light to reach the understory. We found increased cover of oak seedlings (<1 m) in the ground layer at Cap Sauers Holding, which may be due to increased light availability in the understory. However, oak seedlings may not mature into saplings without sufficient light. Increased seedling cover does not provide enough evidence to argue that oak survival has increased. In addition, climatic and biotic factors, such as the timing of mast years, are involved in oak reproduction.

## Characterization of Cap Sauers Holding Forest Preserve

Laatsch (1997) compared the ground-layer species composition at Cap Sauers Holding with the published species lists of various authors (Mead 1846, Curtis 1959, Packard 1988, Bowles and McBride 1994, and Pruka 1995). She found that in 1995, ground-layer composition at the site resembled a forest community rather than a savanna or barrens community. Tree-layer composition and density was forest-like, as was tree canopy cover (>80%), which classifies the site as a forest in most community classification systems. Of the south-ern Wisconsin communities to which we compared Cap Sauers Holding, it more closely resembled tree composition for drymesic forest than for dry forest, mesic forest, oak openings, and oak barrens (Laatsch 1997). To reestablish conditions similar to those of the early 1800s at Cap Sauers Holding, a more radical reduction in tree density and canopy cover is necessary.

## Long-term Vegetation Change

Cap Sauers Holding shows a pattern of increased tree density over the last 180 years similar to that of other studied oak sites (McCune and Cottam 1985, Abrams 1992). However, in contrast to Noe Woods (McCune and Cottam 1985), oak species composition has shifted. McCune and Cottam (1985) reported a lack of recruitment of the dominant white and black oak at this site. At Cap Sauers Holding, white oak was the dominant tree in 1821 and red oak, a pioneer species on mesic sites (Peet and Loucks 1977, Adams and Anderson 1980), has been recruited as a canopy dominant since that time. Both species have increased in density since presettlement times, with red oak increasing proportionally more than white oak so that they now share dominance. Perhaps Cap Sauers Holding is a more mesic site than Noe Woods, allowing red oak to increase at the former. However, in the absence of disturbance, community succession will likely lead away from dominance of this pioneer species. Red oak had low density and canopy cover in the shrub layer at Cap Sauers Holding in 1988 and 1995, and white oak was completely absent in this size class. These conditions could lead to a lack of red and white oak recruitment into the canopy unless a more effective fire management pro-gram is applied (Abrams 1992).

**Table 5. Density (stems/ha) of suppressed vegetation (woody plants <1.4 m in height) at McClaughry Springs in 1992 and 1995.**

| Species | 1992 | 1995 |
|---|---|---|
| *Parthenocissus quinquefolia* | 77,414 | 93,633 |
| *Rhus radicans* | 13,084 | 2795 |
| *Viburnum dentatum* | 5452 | 12,578 |
| *Cornus racemosa* | 3271 | 9783 |
| *Fraxinus* spp.[a] | 6542 | 4193 |
| *Rhamnus* spp.[a] | 1090 | 5590 |
| *Crataegus* spp. | 4361 | —[b] |
| *Acer saccharum* | 4361 | |
| *Viburnum acerifolium* | 3271 | |
| *Viburnum lentago* | | 2795 |
| *Lonicera* spp. | | 2795 |
| *Vitis riparia* | | 1398 |
| *Rubus* spp.[a] | 1090 | 1398 |
| *Ulmus americana* | | 1398 |
| *Rosa multiflora* | — | 1398 |
| *Prunus serotina* | 1090 | |
| *Acer negundo* | 1090 | |
| TOTALS | 122,118 | 139,750 |

[a] For these groups, genera were recorded in 1992. In 1995 species recorded were *Fraxinus americana*, *Rhamnus frangula*, and *Rubus allegheniensis*.

[b] No record of a species is indicated by —.

At McClaughry Springs, tree density has increased since presettlement times and oaks have increased in density. White oak was dominant in 1821 (according to GLO surveys) and has maintained that dominance. White oak and red oak densities increased substantially over a three-year period (1992-1995). As at Cap Sauers Holding, red oak increased proportionally more than white oak since presettlement times, and this trend continued between sampled years. At this site, oak is present in the intermediate class at low densities, but is greatly exceeded by black cherry, elm, and ash; black cherry and elm were reported to increase at Noe Woods in the absence of disturbance by fire (McCune and Cottam 1985). Lack of oak recruitment and the increase of small-stature, short-lived trees are concerns to managers of oak woodlands.

**Table 6. Density of intermediate vegetation (stems >1.4 m tall that do not reach the canopy) at McClaughry Springs in 1992 and 1995.**

| | Density (stems/ha) | |
|---|---|---|
| Species | 1992 | 1995 |
| TREES | | |
| *Prunus serotina* | 218 | 408 |
| *Fraxinus americana* | | 356 |
| *Fraxinus pennsylvanica* | | 98 |
| *Fraxinus* spp. | (233) | (454)[a] |
| *Ulmus rubra* | | 225 |
| *Ulmus americana* | | 172 |
| *Ulmus spp.* | (140) | (397) |
| *Carya ovata* | 31 | 140 |
| *Quercus rubra* | 47 | 80 |
| *Quercus alba* | 47 | 51 |
| *Quercus ellipsoidalis* | 16 | — |
| ***Quercus*** spp. | 47 | |
| *Acer negundo* | 16 | 78 |
| *Juglans nigra* | 16 | 69 |
| *Tilia americana* | 47 | 38 |
| *Acer saccharum* | 156 | 31 |
| *Ostrya virginiana* | 16 | — |
| SHRUBS | | |
| *Crataegus* spp. | 498 | 780 |
| *Viburnum dentatum* | 140 | 539 |
| *Rhamnus frangula* | — | 196 |
| *Rhamnus cathartica* | | 9 |
| *Rhamnus spp.* | (31) | (205) |
| *Lonicera tatarica* | 16 | 149 |
| *Prunus virginiana* | — | 60 |
| *Rosa multiflora* | | 27 |
| *Viburnum lentago* | | 18 |
| *Cornus racemosa* | 31 | — |
| TOTALS | 1742 | 3524 |

[a] Numbers in parentheses represent totals for all species present in a particular genus.

**Table 7. Density, basal area, and importance value[a] for dominant woody species at McClaughry Springs in 1992 and 1995.**

| | Density (stems/ha) | | Basal Area ($m^2$/ha) | | Importance Value[a] | |
|---|---|---|---|---|---|---|
| **Species** | **1992** | **1995** | **1992** | **1995** | **1992** | **1995** |
| *Quercus alba* | 87.8 | 102.6 | 21.0 | 24.8 | 49.2 | 47.6 |
| *Quercus rubra* | 34.0 | 90.5 | 6.3 | 8.1 | 16.7 | 26.0 |
| *Quercus ellipsoidalis* | 23.3 | - | 1.6 | - | 8.0 | - |
| *Fraxinus* spp.[b] | 21.5 | 36.2 | 0.7 | 1.4 | 6.2 | 8.2 |
| *Quercus macrocarpa* | 10.7 | 15.1 | 3.9 | 4.7 | 7.7 | 8.2 |
| *Quercus velutina* | 10.7 | 9.1 | 3.7 | 3.2 | 7.5 | 5.4 |
| *Carya ovata* | 7.2 | 3.0 | 0.9 | 0.1 | 2.9 | 0.7 |
| *Prunus serotina* | 3.6 | 6.0 | 0.1 | 0.2 | 1.0 | 1.4 |
| *Juglans nigra* | - | 6.0 | | 0.2 | | 1.3 |
| *Tilia americana* | -- | 3.0 | | 0.1 | | 0.6 |
| *Ulmus americana* | | 3.0 | | <0.1 | | 0.6 |
| *Populus deltoides* | 1.8 | - | 0.2 | | 0.7 | |
| TOTALS | 200.6 | 274.5 | 38.3 | 42.8 | 100.0 | 100.0 |

[a] (relative density + relative dominance)/2

[b] In • 1995 *Fraxinus* spp. included only *Fraxinus americana.*

## CONCLUSIONS

The focus of this research was to determine if existing management practices were successful in accomplishing the restoration goal for a particular portion of Cap Sauers Holding Forest Preserve. In the southwest portion of the preserve that includes our study site, the goal of effecting an open canopy woodland or savanna is true to historic (1821) community character. It is likely that this area burned frequently before the onset of fire suppression. Tree density and basal area at Cap Sauers Holding and McClaughry Springs Forest Preserves have increased over the last 180 years, and tree composition has changed.

Management activity at Cap Sauers Holding, while not having a conclusive positive effect on herbaceous species, has substantially reduced the density and cover of invasive exotic shrubs. The unmanaged site showed an increase in all woody size classes and substantial increases in invasive shrubs in the suppressed and intermediate layers, though species composition in the more mature classes did not change. At the managed site, species composition shifted somewhat toward more mesic species, but density, basal area, and canopy cover of trees were maintained near existing levels and did not increase.

Because of their contribution to invasive shrub control and their potential to restore historic character to the site, prescribed burns are highly appropriate here as they would be in many oak-dominated ecosystems (Abrams 1992). Returning fire to oak savannas and forests reestablishes an important ecosystem process upon which the system depends. Burn frequency could be increased to accomplish the goal of decreasing canopy cover. While some objectives were met at Cap Sauers Holding, continued management is necessary to control exotic species and maintain and restore natural community character.

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