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THE USE OF PRESCRIBED BURNING FOR MANAGING
NATURAL AND HISTORIC RESOURCES IN
THE CHICKAMAUGA AND CHATTANOOGA
NATIONAL MILITARY PARK

A Thesis
Presented for the
Master of Science
Degree
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Jerry L. Faulkner

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ABSTRACT

Chickamauga and Chattanooga National Military Park consists of five reservations in and around Chattanooga, Tennessee. The largest of the five is the Chickamauga Battlefield located about eight miles south of Chattanooga. The mandate of the National Park Service in managing Chickamauga Battlefield is to recreate the historic scene that existed during the battle that occurred there on September 19 and 20, 1863. This goal has resulted in the establishment of a management plan that proposes the use of prescribed burning to reduce hazardous fuel loads and to control alien and "weed species" that are not in keeping with the natural and historic scene.

The purpose of this study is to provide the Park Service with quantitative information regarding the effect of fire on fuel loads and pest species such as Lonicera japonica, Ligustrum sinense, and Rhus radicans. Three study areas were located in Chickamauga Battlefield that reflected the differing pine presence in the forest. Each block was divided into plots and a grid system was used to locate sample quadrats in each plot. Fuel weights, above ground biomass of honeysuckle, and counts of privet and poison ivy were collected both before and after prescribed fire. Two

plots were burned during the fall of 1985 and six more during the following winter while two plots in each block remained untreated controls. Additionally one fourth of each of the 14 blocks was treated with glyphosate (Roundup) to test for the use of fire as a herbicide pretreatment. This was a randomized block design. Analyses of data were done using the General Linear Model of the Statistical Analysis System.

Prescribed burning did significantly reduce fuel loads and the biomass of honeysuckle on burned plots. There was a statistically different response in fuel load reduction between fall and winter burns but no important difference between the response of the different blocks. Poison ivy significantly increased on burn plots while privet counts did not vary significantly. Again there was no significant difference between the response of plots in different blocks.

Applications of glyphosate negatively impacted all three target species. Honeysuckle appeared to be damaged more readily on untreated plots while no difference in response was noted on privet. Significantly more poison ivy growing points were killed by herbicide applications on burned plots than on unburned plots.

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I. INTRODUCTION

The Chickamauga and Chattanooga National Military Park consists of 5 reservations located in an around Chattanooga, Tennessee. The largest of these is the Chickamauga Battlefield located approximately 8 miles south of Chattanooga near Ft. Oglethorpe, Georgia (Figure 1). The Battlefield lies in Catoosa and Walker counties, Georgia and consists of 5,283 acres of forest and mowed fields (NPS, 1985). The area is in the Great Valley of the Ridge and Valley province and has been characterized by Wharton (1978) as lying in the Chickamauga valley. The Battlefield is level to gently rolling and varies only 120 meters in elevation from the low point of 109 meters above sea level at its eastern boundary along Chickamauga creek to the highest peak of 229 meters above sea level at Snodgrass Hill in the northwest corner of the park. The area is underlain by Knox dolomite and Chickamauga limestone (DeSelm, 1984 and Wharton, 1978).

The natural vegetation of the area probably consisted of an oak-hickory forest with varying degrees of pine presence (Kuchler, 1964). Stands containing trees over 110 years in age have been recorded as being composed of black oak, post oak, southern red oak, and scarlet oak with

mockernut hickory (Wharton, 1978). Lipps (1966) reported that similar Knox formations in Floyd County, Georgia contained pine, red oak, post oak, chestnut, and hickory at the time of the 1832 Georgia Land Survey. Today the Battlefield remains an oak-hickory-pine forest with the percentage of pine ranging from very low levels to areas where pine is the dominant. The understory of the forested areas contains maple and dogwood. The shrub and herbaceous layer in many areas is dominated by Rhus radicans and the aliens, Lonicera japonica and Ligustrum sinense. A total of 585 species were recorded in the Battlefield (VanHorn, 1981b) of which 87 (23.6%) were considered to be aliens (VanHorn, 1981a). Approximately 10 acres of cedar glades may be found where soils over the calcareous substrate are particularly thin.

Chickamauga Battlefield has a long history of disturbance. The area was involved in agriculture from its settlement in the late 1820's and 1830's until the time of the fierce fighting that occurred on September 19 and 20, 1863. A large portion of the vegetation was destroyed during the battle by the use of heated cannon balls which set the woods on fire (Staub, 1985). The area was established as a National Military Park in 1890. Boynton reported that extensive clearing of the underbrush took place in order to bring the battle lines into view. As a result he states

that "carriages can now drive in all directions through the great forests" (Boynton, 1895).

As a National Military Park the reservation was under the control of the Secretary of War and was at the disposal of the military. An Army post existed inside the Battlefield from 1898 until 1945 and at one time was occupied by 71,000 men and 8,400 horses and mules. Extensive areas were in pasture during the Spanish-American War although plantings of native tree species did occur in 1905 (Annual Report, 1900-1916). The administration of the area was placed in the hands of the National Park Service in 1933..

The purpose of this study was to evaluate the effectiveness of fire as a resource management tool to meet the objectives of the National Park Service in managing natural and historic resources within the Chickamauga and Chattanooga National Military Park (hereafter CCNMP). These objectives are centered around the primary goal of the National Park Service in managing CCNMP which is "to recreate the historic scene preserving the park as closely as possible with its 1863 appearance" (NPS, 1985). More specifically these goals are: (1) to reduce the hazard of wildfire that threatens to destroy the park forest; and (2) to recreate the historic scene of 1863 through the

manipulation of vegetation and the elimination or control of alien vegetation (Staub, 1985).

The need for information of this nature arose with the adoption of the 1985 Fire Management Plan for CCNMP which proposed the use of prescribed burning to achieve the objectives stated above. Although the literature regarding the use of prescribed burning is voluminous (Cushwa, 1968) there are deficiencies in our knowledge of the use of fire as a management tool. Most studies involving prescribed burning are centered around commercially important tree species. Few studies have dealt with the mixed stand types present at CCNMP and studies of fire effects in upland and bottomland hardwoods have been deemed a low research priority (Martin et al., 1979). Scant attention has been paid to the effects of fire on the herbaceous and shrub layer (Omi, 1982). In addition the effects of seasonality of burn have not been explored and the effects of fire on specific species is scarcely known outside of a few commercial tree species.

This study attempted to provide information in these areas by investigating the following questions:

1. Will prescribed burning reduce the fire hazard in CCNMP by reducing the existing fuel load?
2. Does seasonality of burning have a significant effect on fuel reduction?
3. Can prescribed burning control alien and

"weed" species that detract from the historical scene?

4. Will seasonality of burn significantly affect the effectiveness of fire as a control for alien and undesirable vegetation?

5. Can prescribed burning be utilized to make herbicide treatment more practical?

This study endeavored to provide answers to the questions listed above by providing quantitative measurement of fuel loads and actual counts of "weed" species. Data was collected before and after treatment and on untreated control plots to provide a basis for the statistical comparison of the effectiveness of prescribed burning. Three species of a particularly undesirable nature were chosen as targets for study. Lonicera japonica, Rhus radicans, and Ligustrum sinense were measured prior to and following treatment to determine fire mortality of these species.

Lonicera japonica (hereafter honeysuckle) was introduced from Asia as an ornamental prior to 1860. It was first collected as an escape in North Carolina in 1891 (Patterson, 1976). It was later promoted as an erosion control plant and a cattle forage. In some areas it is still cultivated as a wildlife food and cover crop. Honeysuckle is an important winter forage for deer (Segelquist et al., 1971). Because of its tendency to sprout at the nodes it reproduces quickly. Its rapid growth has

earned it the description of being "a most pernicious and dangerous weed" (Fernald, 1950). Honeysuckle forms dense mats of vegetation that smother seedlings, shrubs, and saplings (Cain, 1985) and climbs tree trunks that are too large to be pulled down. The latter climbing action results in the formation of "fuel ladders" that increase the possibility of surface wildfires becoming crown fires. This is the case at CCNMP. Honeysuckle is rapidly displacing native species at many areas in the park (VanHorn, 1981a).

Leatherman (1955) stated that "no practical method of controlling honeysuckle had been found where it has spread over large areas of low value land." Cutting has been proposed as a control if the cutting is repeated frequently so that there is no time for recovery (Leasure, 1950), but other reports indicate that it merely causes the plant to form a low mat (Stransky, 1984). The latter supports observations made at CCNMP in a field that has been mowed repeatedly for an unknown number of years. In more recent times a variety of herbicides have been utilized successfully in the control of honeysuckle (Cain, 1985; Warbach, 1953; Little and Somes, 1967). Roundup (glyphosate) and 2,4-D have been used for honeysuckle control (Leasure, 1950; Miller, 1985) although Ahrens et al. (1985) reported that two applications of Roundup were required for complete necrosis. Neither physical removal nor herbicide treatment

alone are practical at CCNMP. Because of the very dense growth of honeysuckle and the large area involved any type of physical removal would be too labor intensive to be practical. The magnitude of the growth would also result in prohibitive cost of herbicide treatment. In addition the dense mats would require broad scale non-selective spraying that would destroy desirable vegetation.

Prescribed burning is a viable alternative to physical removal or herbicide treatment. Although some sources indicate that fire is not a suitable method for controlling honeysuckle (Leatherman, 1955) and others indicate that burning even promotes growth (Hodgkins, 1958) there are reports of successful use of fire (Warbach, 1953; Barden and Matthews, 1980). Fire typically consumes all of the above ground parts of the plant and curtails runner development more than mowing (Stransky, 1984). Burning also inhibits the establishment of new colonies (Brender, 1961). Because honeysuckle does not grow well in climax oak-hickory (Leatherman, 1955) as a result of the deep shade (Blair, 1982), burning may be particularly effective at CCNMP where most of the honeysuckle exists in nearly mature stands. Another factor that may favor the use of fire at CCNMP is the evidence that fire opens dense mats of honeysuckle making it more available to deer browse (Stransky, 1984). CCNMP has a large deer herd and deer have been known to

eliminate honeysuckle where herds are concentrated in small areas (Howard, 1973).

Captain John Smith is credited with the first record of Rhus radicans (hereafter poison ivy) in North America. He named it after its climbing habit similar to English ivy and its poisonous nature which "causeth itchyng (sic), and lastly, blisters" (Gillis, 1971). The dermatitis that results from poison ivy plants is the result of a catechol present in all parts of the plant that elicits a protein allergic reaction from skin cells. Poison ivy occurs repeatedly on disturbed soils and calcium seems to be the most important soil element in areas where it grows profusely (Mulligan and Junkins, 1977). Both of these factors are true at CCNMP. It spreads profusely by horizontal root stocks and a trunk bearing 38 annual growth rings with a 9 centimeter diameter has been reported (Gillis, 1971). A trunk of similar dimensions was observed at CCNMP. Poison ivy growths at CCNMP also form thick mats that inhibit the growth of other vegetation and climb standing trees forming "fuel ladders." Perhaps the only redeeming value of poison ivy is as a wildlife cover and food source. The fruits are particularly favored by quail and flickers (Mulligan and Junkins, 1977).

Control of poison ivy is particularly difficult. If there are a relatively few plants they may be removed by

grubbing. Mowing is ineffective. A seedling two months old usually has a root that one mowing will not kill (Crooks and Klingman, 1971). Herbicides work well (Crooks and Klingman, 1971) and testing indicates Roundup is especially effective (Shaw and Williams, 1985; Lynn et al., 1979). Although these methods may be successful they are not feasible for the dense growths that occur in CCNMP.

Perhaps the single most important factor to consider in using fire for the control of posion ivy is the fact that persons can be affected by particles carried by the smoke of burning plants (Crook and Klingman, 1971; Mulligan and Junkins, 1977). Reports that fire may increase the production of poison ivy have been based on observation alone and not on quantitative measurement (Hodgkins, 1958). Fire is an unknown force in affecting poison ivy growth and reproduction.

Privet (Ligustrum sinense) is a European import that has become naturalized (Fernald, 1950). Its primary horticultural use is in the formation of hedges. Patterns at CCNMP indicate that much of the privet that exist there is reproduction of plantings made during the use of the battlefield by the Army. Privet spreads easily due to its profuse production of fruits which are a favorite of many song birds and bob-white quail (McRae, 1980). In CCNMP there are dense thickets of privet with individual plants

approaching three meters in height. Privet is a semi-evergreen at this latitude.

Any hedge trimmer can attest to the fact that cutting is an ineffective method of eliminating privet. The plant sprouts profusely from stumps resulting in even denser growths. Herbicides including Roundup appear to be effective (James and Mortimer, 1984) although Neal et al. (1985) report that foliar absorption on a similar species (Ligustrum japonicum) is limited on leaves that have overwintered. Again because of the dense growths and the large area involved, exclusive herbicide treatment of privet at CCNMP is impractical.

Although no studies regarding the use of fire for controlling privet could be located in the literature there is reason to believe that prescribed burning may be an effective means of controlling privet. The habit and physical characteristics of privet are very similar to many hardwood species that are controlled by prescribed burning in Southern commercial plantations. The thin tight bark of privet exposes the vascular cambium to temperatures that would be fatal to the plant. Although Chaiken (1952) reports that repeated fires can kill hardwood root sprouts it remains to be seen whether burning will promote the sprouting of privet as cutting does.

The previous policy of fire exclusion at CCNMP has resulted in dangerous accumulations of fuel. Particularly in areas where the percentage of pine is large, the litter layer results in fuel loads that are very high. In addition, the dense growth of honeysuckle and poison ivy provide additional sources of fuel and "ladders" that could result in a destructive crown fire.

Historically, fire has been used freely in the South to reduce fuel loads and to keep the annual undergrowth in check. The South is remarkable for the absence of large destructive fires until the advent of industrial forestry and fire exclusion in the 1930's (Pyne, 1982). Our "pappies" knew what modern forestry did not learn until much later. Prescribed fire is an effective and inexpensive means of reducing fuel loads in forests (Sackett, 1975). No other practical management tool exists where dangerous accumulations of combustible fuels build up (Mobley et al., 1977).

Not very many years ago a study such as this would have been inconceivable. Prior to 1947 no textbook of ecology recognized fire as a factor of plant ecology (Daubenmire, 1968) and suggestions of the use of prescribed burning were derogatorily labeled as "Paiute forestry" (Pyne, 1982). In 1924 burning became an official heresy in the Forest Service (Pyne, 1982).

Today the national parks are letting fire take a more natural role in vegetation management and are using it as a management tool to restore the natural vegetation (Wright and Bailey, 1982). The importance of fire and the effectiveness of prescribed burning are widely recognized. Fire is an important factor in ecosystems if for no other reason than that mankind is able to control it to a far greater extent than other limiting factors (Odum, 1971). Although the biological response to fire can vary widely based on probabilistic events and the genetic potential of the community (Pyne, 1982) the use of carefully designed prescriptions results in amazingly accurate outcomes. Fire is recognized as a legitimate tool for reducing fuel loads, reducing understory for aesthetic reasons, and controlling undesirable vegetation. Although most or all of these objectives could be achieved by other means the chief advantage of using fire is its low cost (Hare, 1961).

II. PROCEDURES

In preparation for initiating a prescribed burn study a detailed fire management plan was created by CCNMP personnel (Staub, 1985). The entire park was divided into three Fire Management Areas. Within these three Management Areas, two Fire Management Zones were established. The two Zones are Fire Protection Zones and Fire Operations Zones. Fire Protection Zones were areas of complete and immediate fire suppression. Because of the close proximity of residential areas all of Fire Management Area 2 (Lookout Mountain Reservation) and Fire Management Area 3 (Signal Point, Missionary Ridge, and Orchard Knob) were classified as Fire Protection Zones. Additionally areas on the perimeter of Chickamauga Battlefield were classified as Fire Protection Zones for the same reason. The area classified as a Fire Operations Zone is located in the core of the Chickamauga Battlefield (Figure 2) and was further subdivided into Fire Management Units (Staub, 1985).

Under the guidelines established in the Fire Management Plan, three study areas were selected in the Fire Operations Zone of Chickamauga Battlefield. These areas (hereafter referred to as blocks) were selected to take full advantage

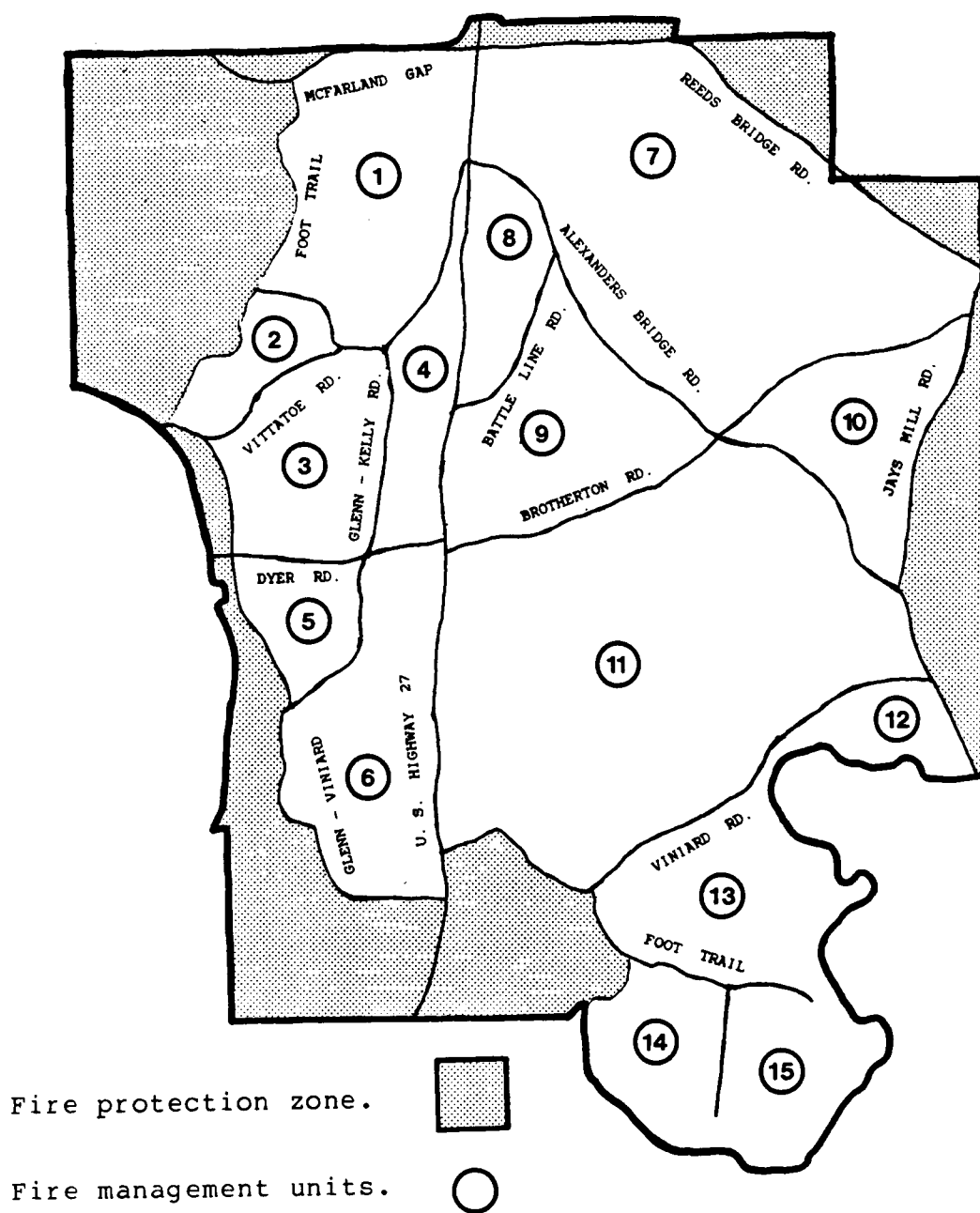


Figure 2. Fire Management Units of Chickamauga Battlefield.

of existing roadways and streams to act as fire lines. None of the blocks were located along U.S. Highway 27 in order to not pose a traffic hazard during burning. Consideration was also given to the accessibility to the blocks by fire fighting equipment in the event of an escape.

Blocks were also selected to reflect the variation of the percentage of pine in the forest. Concentration of pine was determined by measuring diameter at breast height of all stems larger than 10 centimeters on two randomly selected plots within each block. Percentage was calculated based on basal area of the selected plots. Block Number One, located in Fire Management Unit Three (Figure 2), was less than 25 percent pine (Table 1). Block Two was between 25 and 75 percent and is located in Fire Management Unit One. Block Three was more than 75 percent pine and was located in Management Unit Ten.

Each block was divided into plots. Plots were 33 meters square giving a total area of 1089 square meters (approximately 1/4 acre). This size was deemed to be large enough to produce a fire that would carry through the entire plot and at the same time be small enough to be manageable by a minimum number of employees. Plots were laid out using a 50 meter tape and applications of the Pythagorean theorem. Each plot was further divided into four equal, square subplots for herbicide testing. The four corners of

Table 1. Percentage of Pine Basal Area by Block.

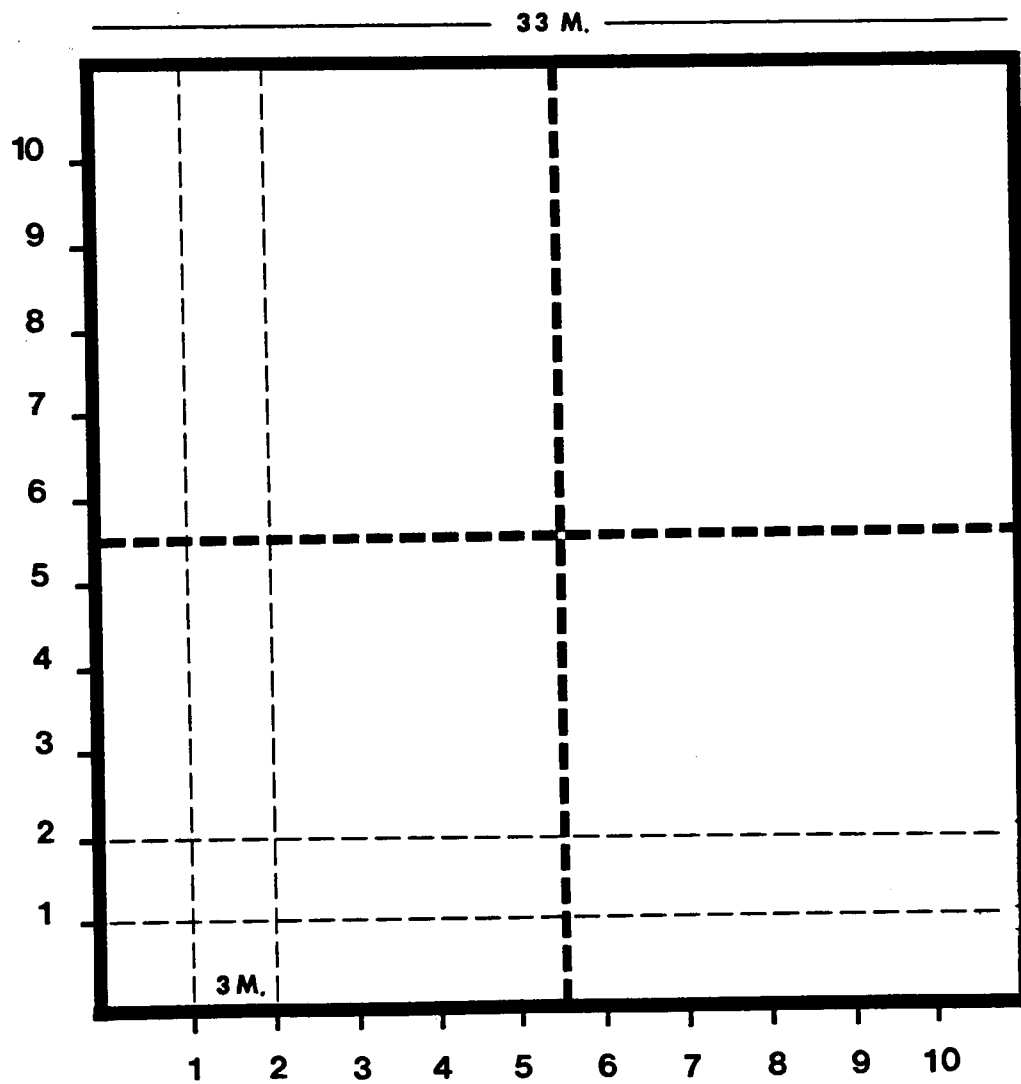
Block Number	Basal area sq.cm.		Percentage of Pine
	Hardwoods	Pine	
1	42006.6	6755.5	13.9
2	26361.2	50748.3	65.8
3	5429.6	70843.0	92.9

each plot were marked with 36 inch sections of 1/2 inch galvanized conduit driven 18 inches into the ground. The southeast corner post of each plot was tagged with an aluminum tag bearing an assigned number for each plot. Plots 1 through 10 were in Block One, 11 through 20 in Block Two and plots 21 through 30 were in Block Three.

A space of at least 2 meters was left between adjacent plots for the purpose of constructing fire lines (Wright and Bailey, 1982). Fire lines were constructed utilizing a gasoline powered shrub trimmer, hand tools and power mowers. Combustibles were removed to bare mineral soil and all procedures outlined in the Fire Management Plan for CCNMP (Staub, 1985) were followed.

Plots for burning and subplots for herbicide treatment were selected at random using a random numbers table. Two plots in each block remained unburned controls.

A grid system using the eastern and southern sides of each plot as the "x" and "y" axis respectively was used to locate sampling points within each plot. Each axis was divided into three meter sections and numbered one through ten. A random numbers table was used to select the coordinates of sample points with ten represented by zero. This avoided the location of sampling points on any of the perimeter lines and none were closer than 3 meters to the edge (Figure 3). This was done to minimize the possibility



Plot boundaries. **—————**

One-quarter plot fractions. **-----**

Grid system for location of sample points. **-----**

Figure 3. Plot Design.

of effects from fire line construction and plot ignition influencing data.

Each sample point was the center of a circular quadrat one square meter in area. A length of galvanized conduit was temporarily driven into the ground at each sample point. A metal key ring with an appropriate length of small chain was placed over the conduit. A screwdriver in the last link of the chain was a convenient handle for scribing the perimeter of the quadrat with the conduit as the axis.

Pre-treatment sampling consisted of locating 11 quadrats in each of the 30 plots. Ten of the quadrats were for sampling target species and one for sampling fuel loads. All sample points were located and marked with wire road flags prior to the commencement of sampling in order to minimize time between first and last plot sampling.

Fuel load sampling consisted of the collection of all combustibles less than one inch in diameter within the perimeter of the circular quadrat. Living material as well as litter was collected and placed in pre-marked paper bags. The sample was dried in a forced air oven at 65° C. to a constant dry weight (NPS, 1982). Weights minus tare were recorded in grams to the nearest tenth of a gram.

Honeysuckle was sampled in a similar manner. All above ground biomass inside the quadrat was clipped and placed in pre-marked paper bags. Runners entering or exiting the

quadrat were severed at the perimeter and that portion inside the quadrat was collected. The biomass was dried to a constant weight at 65° C. in a forced air oven then weighed and recorded to the nearest tenth of a gram. This method was based on Stransky (1984).

Poison ivy was sampled by counting growing points within the quadrat. Because of the tendency of poison ivy to sprout at each node an adaptation of Brown's (1954) method for sampling grasses with tillers was utilized. A growing point was considered to be any section of a runner more than three inches in length that bore both roots and a foliage bearing stem. Counts were recorded on the paper bag containing the honeysuckle growth for that quadrat and the information transferred to record sheets upon returning from the field.

Privet was also sampled by counting growing points. Individual growing points were defined as the aerial parts of a single root system regardless of the number of stems (NPS, 1982). Privet counts were recorded in the same manner as poison ivy counts.

Sampling following herbicide treatment utilized a slight variation of these procedures. The effect of herbicide on honeysuckle was determined by observation of one-quarter sections of each quadrat. Quadrats were scored from zero to four based on the number of sections that

exhibited more than 50 percent honeysuckle necrosis. Growing point counts of poison ivy and privet were made in each quadrat and each count was classified as "healthy," "damaged," or "dead" based on the foliage condition.

Pre-burn sampling was done between July 1, and July 18, 1985. Post-burn sampling used a new set of quadrats and was done between the dates of September 1, and September 15, 1986. This allowed for a growing season to occur between burning and sampling as recommended by the Prescribed Fire Monitoring Guide (NPS, 1982). Post herbicide sampling was done on May 14, 1987 using three previously unsampled quadrats per subplot.

Burning was carried out by NPS personnel following the guidelines set forth in the Fire Management Plan (Staub, 1985). Parameters used to develop each prescription are listed in Table 2. Ignition was accomplished by using a drip torch containing a gasoline and diesel oil mixture. Fires were strip-head fires with the exception of Plot 24 which required a backing fire because of prescription conditions. The dates and classifications of the burns are recorded in Table 3.

Herbicide applications to subplots of the eight burned plots and the six control plots were done by NPS personnel on April 27 and 28, and May 7, 1987. Two percent glyphosate (Roundup) solution was applied foliarly with a solo portable

Table 2. Burning Parameters (Staub, 1985).

Parameter	Acceptable Values
Fire Line Intensity	4-5 ft.
Rate of Spread	10-25 ft./min.
Midflame Wind Speed	5-10 mph.
Relative Humidity	30-50%
Temperature	30°-80° F.
Burning Index	20-30
Drought Index	300 max.
Ignition Component	20-30
Fuel Moisture	
1 Hour Time Lag	4-10%
10 Hour Time Lag	4-10%
Days Since Last Rain	3-10 Days

Table 3. Dates and Classification of Burns.

Plot Number	Burn Date	Ignition Type	Classification
4	1-16-86	Strip-head	Winter
7	1-16-86	Strip-head	Winter
13	3-05-86	Strip-head	Winter
19	3-17-86	Strip-head	Winter
21	10-11-85	Strip-head	Fall
24	10-11-85	Backing	Fall
26	3-05-86	Strip-head	Winter
27	3-05-86	Strip-head	Winter

mist sprayer equipped with a tip rated at 0.3 liters per minute at eight pounds per square inch of pressure. Quarter plot applications ranged from five to eight liters of solution.

These procedures followed a randomized block design with fractional split plots utilized to establish subplots for herbicide treatment. Samples were nested within plots, plots within treatments, and plots and treatments within blocks.

Statistical analyses were done on an IBM PC-XT personal computer utilizing the Statistical Analysis System. Print and Sort procedures were used to assemble the data. Hypothesis testing utilized the General Linear Model procedure with pretreatment data declared as a continuous variable. The Contrast option was used for specific comparison of treatment effects.

III. RESULTS AND DISCUSSION

Pretreatment sampling revealed that there was a significant difference in honeysuckle abundance in the three blocks. Block Two had the least amount of honeysuckle present per sample while Block One had the largest amount (Table 4). This is probably a response to the variation in shade intensity expected in different stand compositions. This difference in honeysuckle abundance did not produce a significantly ($\alpha = 0.05$) distinct response to treatments among the three blocks.

Honeysuckle responded in a desirable manner to burning. The decline in mean weight in burned plots was significantly different from weights in the control plots although the difference between Fall and Winter burns was not statistically significant (Table 5). The decline of honeysuckle in the control plots was most probably the result of the drought that occurred during the summer of 1986. Observations of yellowing and wilting leaves were recorded during a visit to the area on July 25, 1986.

Honeysuckle resprouting on burned plots began as early as March on plots burned in October or January and was observed in April on those plots that were burned in early

Table 4. Honeysuckle Pretreatment Mean Weight Per Sample.*

Block	Weight **
1	83.7 ***
2	34.4
3	65.1

* N = 300.

** Grams / square meter.

*** All weights are significantly different
at alpha = 0.05.

Table 5. Honeysuckle Mean Weights by Treatment.*

Treatment	Pretreatment Weight**	Posttreatment Weight**	Percent Change***
Control	79.1	60.6	-23.4
Fall Burn	94.4	6.8	-92.8
Winter Burn	165.9	67.4	-59.4

* N = 140.

** Grams / square meter.

*** Control significantly different at alpha = 0.05.
Difference between Fall and Winter burn not signif.

March. Most of the resprouting appeared to come from roots or runners just underneath the unburned portion of the litter rather than from deep soil roots.

Poison ivy counts were not distributed normally but on a Poisson distribution. Transformation of data for analysis was accomplished by converting counts to their square roots.

Analysis showed that the difference between the blocks was not statistically significant (Table 6). It is interesting to note that Block Two again had the lowest number of poison ivy counts.

There was a significant difference in the response of poison ivy to treatment. While control plots showed a decline in the number of growing points, plots that were burned showed an increase (Table 7). The decrease was again probably due to the summer drought and the competition between plants for existing moisture. Burning eliminated dominant plants and permitted sprouting at multiple nodes along the surviving runners and roots. There was also a statistically significant difference between fall and winter burns. Plots that were burned in the fall had a larger increase in the number of growing points than did the winter burn plots.

Observations of the postburn plots indicated that some runners survived under unburned litter. These runners

Table 6. Poison Ivy Pretreatment Mean Count Per Sample.*

Block	Count**
1	11.62
2	9.54
3	19.26

* N = 300.

** Counts not significantly different at $\alpha = 0.05$.

Table 7. Poison Ivy Mean Counts by Treatment.*

Treatment	Pretreatment Count	Posttreatment Count	Percent Change**
Control	10.55	5.30	-49.8
Fall Burn	26.65	38.00	+42.6
Winter Burn	11.98	12.53	+ 4.6

* N = 140.

** Significantly different at $\alpha = 0.05$.

provided a good portion of the resprouting although the majority of regrowth appeared to be from roots that were protected in the soil. Leafing out of poison ivy on control plots was noted as early as mid-March while production on burned plots was not observed until a visit on April 11, 1986. Several large stems entwined around trees showed evidence of burning of the hair like roots on their exterior. These stems were observed on July 25, 1986 to be without leaves and presumed to be dead.

Privet counts also produced a Poisson distribution and were transformed by conversion to square roots. Analysis of pretreatment counts showed a significant difference between plots. Block Two had the largest number of growing points per square meter (Table 8). Block Two is the lowest lying of the three blocks and is poorly drained. The moist conditions seem to favor the growth of privet not only in this block but in other low lying parts of the Battlefield.

Privet was not significantly responsive to treatment by burning. Although there was wide variability in the response to burning there was no statistical basis for accepting the hypothesis that burning affects privet counts (Table 9). Some of the variability may be due to the fact that fire did not carry well in the especially thick privet thickets. This may be a result of the affinity for low lying, damp areas. Another possible explanation may lie in

Table 8. Privet Pretreatment Mean Count Per Sample.*

Block	Count**
1	0.49
2	2.74
3	1.36

* N = 300.

** Significantly different at $\alpha = 0.05$.

Table 9. Privet Mean Counts by Treatment.*

Treatment	Pretreatment Count	Posttreatment Count	Percent Change**
Control	1.28	0.53	-58.6
Fall Burn	0.05	0.20	+300.0***
Winter Burn	2.23	1.85	-17.0

* N = 140.

** Not significantly different at $\alpha = 0.05$.

*** Based on very small number in Fall Burn plots.

the composition of the litter under privet thickets. The litter from privet itself seems to compact very easily. Ranger Danny Howell also observed that thickets of privet act as "umbrellas" preventing the infiltration of litter from canopy trees. Where the fire did kill the above ground portion of privet, vigorous resprouting from the root crown occurred in almost every observed instance.

Fuel loads varied significantly among the three test blocks. Fuel loading was positively correlated with the pine percentage present in the stand. Block Three with the highest percentage of pine had the highest fuel loads (Table 10). The difference in fuel loads did not significantly influence the way the vegetation responded to treatment. Higher fuel loads normally result in hotter fires providing more opportunity for reductions of target species, however, statistical tests did not verify such after one burn.

Fuel loads were reduced by burning. While control plots exhibited a 10.9% increase in fuel loads, burn plot fuel loads decreased (Table 11). The increasing fuel load may indicate that the litter - decomposition system has not stabilized in these stands or it may be a result of premature litter fall as a result of the drought. If a 10.9% increase is imposed on the pretreatment weights of the treated plots then the amount of the decrease by burning would be even greater. There is also a significant

Table 10. Fuel Load Pretreatment Mean Weight by Sample.*

Block	Weight**
1	886.7
2	1159.4
3	1389.2

* N = 30.

** Grams per square meter.

Table 11. Fuel Load Mean Weight by Treatment.*

Treatment	Pretreatment Weight**	Posttreatment Weight**	Percent Change***
Control	1189.5	1318.8	+10.9
Fall Burn	1543.5 (1711.7)****	1411.2	- 8.8 (-17.6)
Winter Burn	1092.6 (1211.7)****	898.6	-17.8 (-25.8)

* N = 14.

** Grams per square meter.

*** Significantly different at $\alpha = 0.05$.

**** If a 10.9% increase is assumed for burn plots as well, then the difference is even greater.

difference between the fall and winter burns with the winter burn producing greater reductions in the fuel load. The difference in the two may be a result of plant material that was not abscised until after the fall burn had already occurred or because of needle fall from scorched pines.

The climbing growths of poison ivy and honeysuckle that had formed fuel ladders were reduced by prescribed burning. Fine fuels present in these ladders were consumed by flare-ups and in most cases the growth was completely severed at about one meter above the surface. Although the remaining stems are now dead, they are composed of larger fuel class material and are effectively separated from possible ignition by surface fires.

Additional non-quantitative observations were made of the response of other vegetation to the burning. Herbaceous vegetation was consumed by the fires. Observations made the following spring noted that where grasses and forbs were present prior to the burn, they were now flourishing. Tuberous and rhizomatous herbs appeared to be released by the fires. In July of 1986 several Arisema dracontium (Green dragon) were observed to have set fruit in one of the burned plots. The above ground portions of woody plants less than five centimeters in diameter were killed by the fire. Vaccinium and Rubus species were consumed although Rubus showed rapid regrowth the following spring and seems

to be favored by the fires. Small oaks that were destroyed by the burns were observed in April of 1986 to be resprouting from root crowns. Small pines appear to have been killed. Larger understory trees such as dogwood showed evidence of scorching of the buds. Dogwoods examined in the spring following burning had many malformed leaves present and apparent damage to apicals was noted. Canopy and subcanopy trees showed little sign of damage. No serious butt burns were noted and the only crown scorch appeared in pines in the subcanopy.

The response of target species to herbicide treatment was also varied. Honeysuckle response to herbicide seemed to be greater on unburned control plots. Quadrats on control plots scored higher than those on burned plots. This may be a response to the larger volume of honeysuckle still present on unburned plots. On burned plots where honeysuckle has been reduced and is often overtopped by other vegetation in the herbaceous layer interception of the spray droplets may have resulted in differences in the actual treatment of honeysuckle.

Privet was also negatively impacted by glyphosate treatment. Although the majority of plants were either damaged or killed by herbicide treatment there was no significant difference between the response of burned and unburned plots (Table 12).

Table 12. Postherbicide Mean Privet Percentages
by Treatment.*

Treatment	Mean % Healthy**	Mean % Damaged**	Mean % Dead**
Control	12.5	37.5	50.0
Fall Burn	0.0	0.0	0.0
Winter Burn	21.2	51.2	27.6

* N = 42.

** Not significantly different at $\alpha = 0.05$.

Poison ivy responded in a desirable manner to the Roundup treatments. A large percentage of poison ivy was damaged or killed by the Roundup. The number of plants that were killed was significantly different between plots. At an alpha of 0.05 the burned plots exhibited a statistically greater response to herbicide treatment than did the control plots (Table 13). Since burning increased the number of growing points the increased mortality may be a response to greater absorption from more leaves of the same plant. Another possible explanation is that the poison ivy released by burning was growing more actively than on unburned plots. Active growth is a requisite for good results from Roundup (Monsanto Co., 1983).

Several factors may have had a mitigating influence on the results of burning as well as herbicide treatments. As previously mentioned, the summer of 1986 was the driest on record for the study area. On August 17, rainfall totals for the year were 19 inches below normal. Additionally the winter preceeding this study had record cold temperatures. During 1985 temperatures dropped to -16° F. at the park weather station. Observations made during the Spring of 1985 noted that much of the normally evergreen honeysuckle and privet had lost foliage due to freezing. The weather occurring during the period of herbicide treatment may have impacted the results. Temperatures during the period

Table 13. Postherbicide Mean Poison Ivy Percentages
by Treatment.*

Treatment	Mean % Healthy**	Mean % Damaged**	Mean % Dead***
Control	12.1	66.6	21.3
Fall Burn	10.9	43.7	45.4
Winter Burn	14.9	54.9	30.2

* N = 42.

** Not significantly different at $\alpha = 0.05$.

*** Significantly different at $\alpha = 0.05$.

immediately following herbicide application ranged from highs in the low 80's to lows in the mid 50's. These are somewhat less than the mid-summer temperatures which produce maximum results.

The characteristics of fire itself can vary widely. The outcome of any fire depends on a series of probabilistic events (Pyne, 1982). Other factors may have influenced the action of the fires included in this study. The topography of the areas involved had some effect on the results of burning by influencing the speed and temperature of the fires. All of the areas burned were level. Fires spread over slopes faster and hotter due to the flames tilting over the unburned fuel and preheating it (Chandler et al., 1983; Wright and Bailey, 1982). Fires over level ground must depend on wind to produce similar tilting. The areas at CCNMP were surrounded by varying patterns of field and forest that produced erratic winds at surface level. This may have resulted in fires that were cooler and consequently less effective at killing targeted vegetation. The topography was also responsible for high soil moisture. Many of the areas were poorly drained resulting in the soil and the lower layer of litter being too moist to permit combustion of all the fuels present and the attainment of temperatures high enough to kill surface roots, runners, or root crowns.

IV. CONCLUSION

The use of prescribed burning in CCNMP had mixed results. The biomass of honeysuckle was significantly reduced. Fuel loads were reduced and the hazard resulting from multiple fuel ladders was lessened. Privet counts were not influenced but large plants were killed and the resprouting from root crowns is significantly shorter. Poison ivy counts increased but the biomass of poison ivy was reduced.

Overall, the effect of the fires was aesthetically pleasing. After the visual impact of the charcoal dissipated and spring growth began, those areas that were burned appeared more open and park like. The target species were still present but their biomass was considerably reduced.

All targeted species responded to herbicide treatment in a desirable manner. Honeysuckle, poison ivy, and privet were damaged and killed by Roundup applications. Only poison ivy exhibited a significant difference in the way it responded on burned and unburned plots exhibiting a larger percentage of dead plants on burned plots. Herbicide

application amounts were similar on burned and unburned plots.

Based on these observations, I would recommend that the Park Service seek other means of management beyond single fall or winter prescribed burns. While these burns did reduce fuel loads and the biomass of targeted species it appears that no long term benefits were achieved. The biomass reduction of privet and poison ivy by burning makes herbicide treatment more convenient but it does not significantly improve the effectiveness nor reduce the cost of herbicide treatment, thus limiting burn/herbicide treatments to small areas of great historical importance or heavy recreational use.

An expanded study to include spring and summer burns plus multiple burns is appropriate before long-term recommendations are possible. Although fuels were reduced, a sufficient fuel base remained to permit reburning within one year using slightly different prescription parameters. It is entirely consistent with the literature that sprouting frequency and vigor could be reduced to acceptable standards once the correct season and frequency of burning is determined.

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