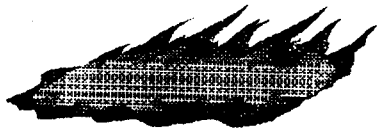


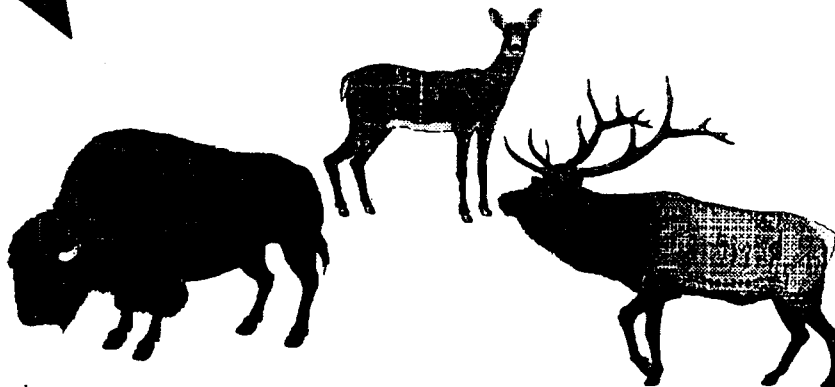
LARGE MAMMALIAN HERBIVORES, PLANT INTERACTIONS, AND ECOSYSTEM PROCESSES IN FIVE NATIONAL PARKS



Final Report to Wind Cave National Park
on Cooperative Agreement 1445-0009-94-1074, Subagreement 2

Prepared by:

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March 31, 1998

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ABSTRACT

Deciduous shrubs of wooded riparian areas may be declining in Wind Cave National Park, South Dakota. It is theorized that encroachment of Ponderosa pine (*Pinus ponderosa*) as the result of fire suppression and heavy utilization of shrubs by elk (*Cervus elaphus*) are contributing to this decline. Using large fenced exclosures and prescribed burning, we investigated the impacts of these factors on shrub production and regeneration. Four hypotheses were proposed: (1) Fire suppression has led to the decline of shrubs in woody draw communities, and conversely reintroduction of burning will lead to an increase in shrub production and regeneration. (2) Excessive grazing has an effect on the production and regeneration of shrubs. (3) Hot fall burns (fall vs. spring) have a greater effect on production and regeneration of shrubs. (4) Some combination of these two factors (grazing and fire suppression) is responsible for the decline in shrub production in woody draws.

Burning reduced shrub canopy volume in areas open to browsing/grazing immediately following burning, but increased regeneration of elm (*Ulmus americana*) and box elder (*Acer negundo*). Herbivory on shrubs in burned plots increased in the summer and winter following burning, particularly on spring burns. Fall burning had a greater impact than spring burning, increasing canopy volume, area and production of *Rosa* spp. and *Ribes aureum*, but suppressed height and growth compared to spring burns. The combination of burning and grazing led to significant decreases in canopy cover, particularly on spring burns. Results suggest that fall prescribed burning could be used to increase regeneration in riparian areas of Wind Cave NP, but that provisions should be made to keep browsing intensities low immediately following burning.

Introduction

Wind Cave National Park (WCNP) is a small, fenced park in the Black Hills of South Dakota enclosing a mosaic of mixed grass prairie and ponderosa pine communities. The park supports all mammalian herbivores native to the area, including bison (*Bison bison*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), and elk (*Cervus elaphus*). Woody riparian draw communities are a unique component of the WCNP ecosystem. These communities, found along flowing and intermittent streams, support growth of hardwood shrubs and trees. Many western species are at the eastern limit of their distribution in these areas, and conversely, many eastern species are at the western limit of their distribution. The abundance of shrubby vegetation in these draws provides forage and cover for the large ungulates which inhabit the park.

Several significant ecological forces have changed the face of WCNP over the past decade. Dutch elm disease eliminated much of the American elm (*Ulmus americana*) from the riparian tree canopy. Box elder (*Acer negundo*), another dominant tree at the turn of the century, is heavily browsed by elk and deer, and does not withstand extreme winter weather. It may be declining in riparian habitats (Maguder 1983). Ponderosa pine forests have expanded, likely due to policies of fire suppression. Dendrochronological studies indicate that fires occurred every 13 to 21 years in this area from 1820-1910 (Shilts et al. 1980). Pine forests now extend right to the borders of streams in many areas. Park managers are concerned pine may be out-competing hardwood shrubs found in these woody draws through lowering of local water tables and shading. These hypothesized processes, however, have not been verified.

Woody shrubs found in draws appear to be declining. Prior to the present study, high levels of ungulate use had been observed on shrubs, but lowered local hydrology may also be contributing to this decline. A National Park Service study of rare trees and shrubs in WCNP concluded that many rare species were over-mature and suggested that regeneration had been retarded due to wildlife utilization, competition with pines, and lack of available moisture (Smith 1978, Shepardson 1980). Large ungulates are confined to the park in varying degrees. The 8-foot fence surrounding the park confines bison, but elk are able to leave the park through specially designed crossings in the fence. However, it is likely that large numbers of elk also enter the park from adjacent national forest land as well, particularly during the hunting season. The park culls bison annually. The elk herd was also reduced to approximately 250 animals in the park in 1994.

To better manage these unique resources, park managers are interested in impacts of prescribed burning and ungulate herbivory on shrub production, regeneration, and consumption by herbivores in woody draw communities. We used a series of seven exclosures, erected in late 1994, to experimentally examine the effects of herbivory and burning on vegetation. Treatments included: grazed-burned, grazed-unburned, exclosed-burned, and exclosed-unburned. In addition, we tested to see if the effects differed based on whether burns were conducted in spring or fall.

We looked at four key hypotheses in this study. (1) Fire suppression has led to the decline of shrubs in woody draw communities, and reintroduction of burning will lead to an increase in shrub production and regeneration. (2) Excessive grazing reduces the production and regeneration of shrubs. (3) Hot fall burns (fall vs. spring) have a greater positive effect on production and regeneration of shrubs. (4) Some combination of these two factors (grazing and fire suppression) is responsible for the decline in shrub production in woody draws.

Alternatively, (1) reintroduction of fire and elimination of browsing in these systems has no effect on shrub production. (2) Season of burning has no effect on shrub production or recruitment rates. (3) Other factors are contributing to the decline of shrubs in woody draw communities.

Study Area

Study sites were located throughout Wind Cave National Park in the southern Black Hills of South Dakota. Seven sites were chosen in shrub communities located in riparian draws (3 sites on flowing streams, 4 on dry or intermittent drainages). Major shrub species included box-elder (*Acer negundo*), American elm (*Ulmus americana*), currant (*Ribes* spp.), chokecherry (*Prunus virginiana*), American plum (*Prunus americana*), skunkbrush sumac (*Rhus aromatica*) and snowberry (*Symphoricarpos occidentalis*). Elevations ranged from 1100-1300m.

Seven exclosures (approximately 0.5 ha area) were erected in November 1994 to February 1995. Park staff identified which sites were suitable for spring, as opposed to fall, burning based on logistics of prescribed burning. All sites were visited in 1995. Areas adjacent to each exclosure were delineated for grazing treatments and plots to be burned were randomly chosen. Park staff conducted burns in September-October 1995 at three of the new (1994-95) exclosures (Apple Orchard, Highland Creek, and Wind Cave Canyon) and an older (1987) exclosure known as the "black cottonwood" exclosure. The remaining new (1994-95) exclosures (Beaver Creek, Coldspring East, Coldspring West, and Coldbrook Canyon) were burned during May 1996. In May 1997, an escaped controlled burn consumed most of the shrub vegetation in both the Beaver Creek and Coldspring East sites. In July 1997, a heavy windstorm caused a tree to fall on the exclosure fence at Coldspring West, and herbivores were quick to exploit this opportunity. Several ungulate (most likely elk or deer) bedding sites and extensive browsing on elm were found during August 1997. Fence was repaired in August 1997, and measurements on this treatment could resume as soon as summer 1998.

Methods

Field data collection was conducted in August and September 1995-97 and April 1996-97. At each site, five 9.3 m² (100 ft²) circular plots were established in each of four treatment areas: exclosed-unburned, exclosed-burned, grazed-unburned, grazed-burned. Data collected on each plant included: species; canopy diameters (widest and perpendicular to widest diameter); plant height; number of stems; estimate of percent of canopy dead. On every fourth individual of each shrub of each species a subsample of the number of browsed and unbrowsed leaders; twig basal, tip, and browse diameters. A large sample of twigs were collected from various species at each site in spring and summer 1996. These twigs were oven-dried at 55° C for 48 hours, separated into leaves and twigs (when appropriate), and weighed to the nearest 0.01 grams. Production was estimated by determining average weight of current year twigs and multiplying by the total number twigs produced.

Measures were collected during April to estimate winter consumption, and August to estimate summer consumption. Percent leader use was determined using the equation :

$$\% \text{ leader use} = \frac{a}{a+b}$$

where a = # browsed leaders and b = # unbrowsed leaders. Average percent current year twig removed was determined using the method of Jensen and Urness (1981) and Pitt and Schwab (1990) following the formula:

$$\% \text{ twig use} = \frac{100(D_p - D_t)}{D_b - D_t}$$

where D_p = twig diameter at point of browsing, D_t = diameter of a representative sample of twig tips, and D_b = basal diameter of current year's twig growth. Total percent consumption was determined by multiplying % leader use by % twig use.

All sites were mapped to identify location, height, and stem counts of trees and shrubs of *Acer negundo*, *Populus balsamifera*, *P. deltoides*, *Ulmus americana*, *Pinus ponderosa*, *Fraxinus pennsylvanica*, and *Salix* spp. in 1995 and 1996. A tally of stems and heights of species of interest was conducted in the old "black cottonwood" exclosure and adjacent grazed/browsed areas (~150 m from exclosure) in 1995, prior to prescribed burning of the larger area surrounding it, and again in 1996. No unburned controls exist for this site and it was not included in any analyses of production or consumption for sites with new exclosures.

Statistical analysis was performed using Statistical Analysis Software (SAS) version 6.11. PROC GLM was used to analyze a two-factor ANOVA for an unbalanced design, with burning/grazing treatment and season of burn as factors. Analyses were done separately for each

year and for all treatments in each season as well. All variables had a constant added to them and were then log transformed to stabilize variance. We concluded significant differences when p-values for the F-test were less than or equal to 0.05. Frequency histograms of stem tallies were visually analyzed for trends, and apparent trends are included in the results.

Results

Consumption

Burning attracted elk to forage in many sites as was indicated by increased levels of consumption in the year immediately following burning. Percent leader use (pooled across all sites) was significantly higher ($p=0.0349$) in burned areas in winter 1996-97 (Table 1). Percent leader use in summer 1996, was slightly higher ($p=0.0558$) in areas burned in spring versus unburned plots in the same area and leader use on spring burn plots was even higher during winter 1996-97 ($p=0.0497$) (Fig. 1a). Percent leader use (unburned plots pooled across all sites) was greater in winter 1995-96 than 1996-97, and summer leader use was greater in summer 1996 than 1997 (Fig. 1b). Percent consumption of total plant production was also greater ($p=0.0273$) in summer 1996 than summer 1997 (Table 1).

Shrub production

Burning and grazing significantly reduced total shrub canopy volume and area ($p=0.0016$, $p=0.0079$) at sites burned in spring compared to their adjacent unburned plots in 1996--the growing season immediately following burning (Fig 2a). Grazed plots burned in spring also had significantly reduced canopy volume and area than those burned in fall (Fig 2b). Fall burning suppressed height growth of shrubs compared to spring burning. Average heights of plants in spring burn plots were 120% greater ($p=0.0077$) than fall burn sites (Fig. 3).

Fall burning increased canopy volume and area of *Rosa* spp. by 2.5 (volume) to 4.5 (area) times (volume $p=0.0003$, area $p=0.0007$) over spring burns (Fig. 4a). In 1997, canopy area of *Rosa* spp. was 3 times greater ($p=0.0137$) in fall burns than spring burns (Fig. 4b).

Protection of elms (*U. americana*) from fall burning and grazing allowed them to increase in height. On average elms were taller ($p=0.0345$) in exclosed-unburned treatments than grazed plants in 1996 (Fig. 5). Total number of elm stems increased in grazed-burned, exclosed-burned, and exclosed-unburned treatments in 1996 in four exclosures (Fig 6a-d), but in only one grazed-unburned treatments were there increases in elm stems (Fig. 6d).

Fall burning led to decreased heights of the currant, *Ribes aureum*. Plants were taller ($p=0.0155$) in exclosed-unburned than burned plots (Fig. 7). Fall burning increased canopy volume, canopy area, and production of *R. aureum*, however, slight pretreatment differences

were found in 1995 for canopy area and volume ($p=0.0450$, $p=0.0392$) (Fig. 8a). Significance levels were much higher in 1996 ($p=0.0004$ volume, $p=0.0006$ area) and 1997 ($p=0.0014$, $p=0.0037$) (Fig. 8b). Production ranged from 5-40 times ($p=.0074$) greater in sites that were burned in the fall than all unburned plots and plots burned in the spring, regardless of whether they were grazed or not (Fig. 8c). In 1997, production was still greater ($p=0.0098$) in fall burn plots than spring burn plots, but no interaction based on exclusion from grazing or burning was evident (Fig. 8d).

Numbers of box elder stems increased in treatments that were exclosed, particularly when unburned (Fig. 9a-b) in two exclosures. In the black cottonwood exclosure, which had been burned many years prior to this study as well as in 1995, increases were seen in black cottonwood (*Populus balsamifera*) and plains cottonwood (*Populus deltoides*) after burning, but the increases were much greater within the exclosure than in grazed areas (Fig. 9c-d).

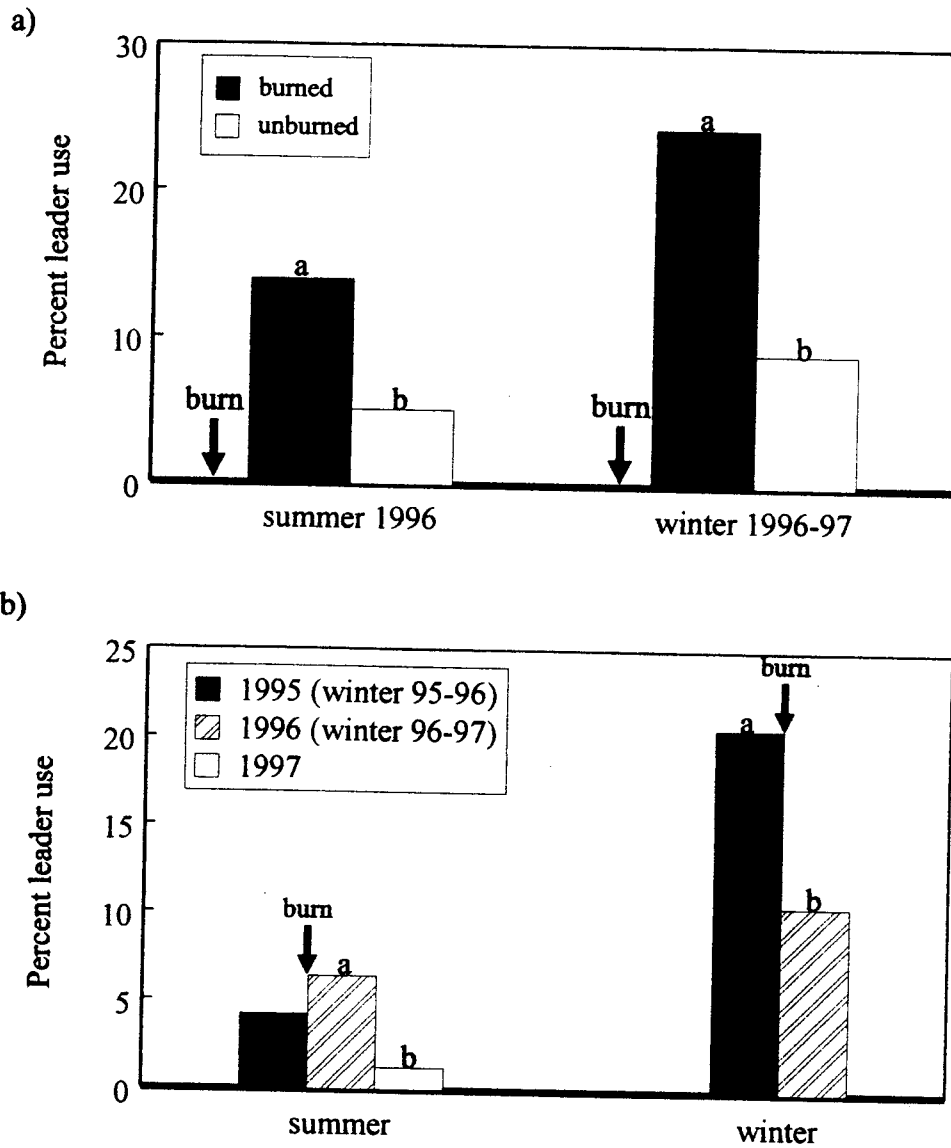
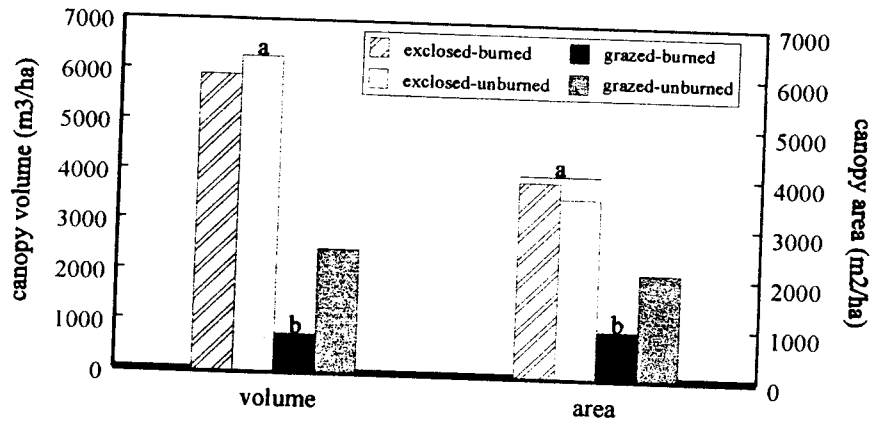


Figure 1: Ungulates consumed more leaders of shrubs in plots burned in spring vs. unburned plots (a). Summer leader use was greater in 1996 vs. 1997 and winter leader use in 1995-96 was greater than 1996-97 (b). Different letters denote significant ($p < 0.05$) differences.

a)



b)

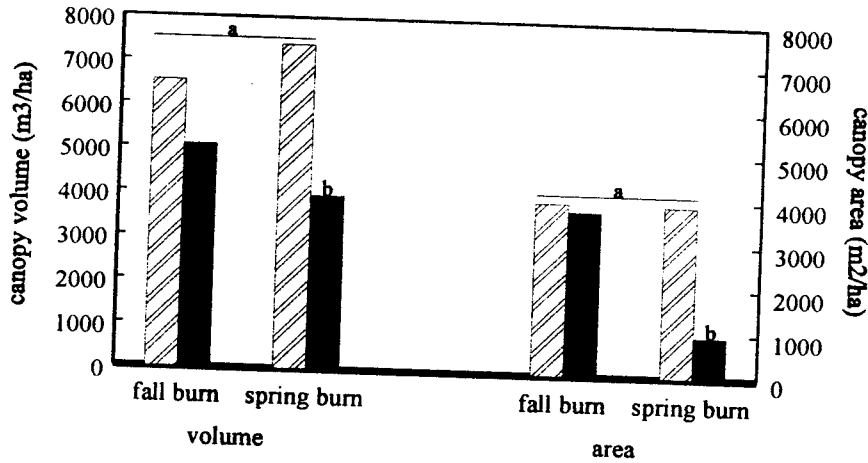


Figure 2: Total shrub canopy volume and canopy area on spring burns (a) and compared between spring and fall burns (b). Different letters denote significant ($p < 0.05$) differences within volume and area.

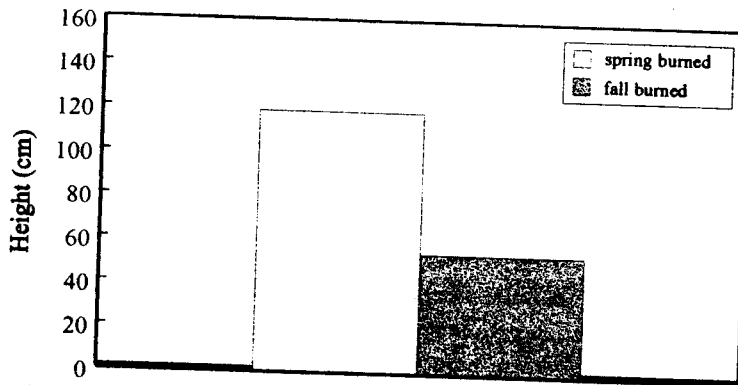


Figure 3: Average height of shrubs in spring burns were significantly taller compared to fall burns in 1996.

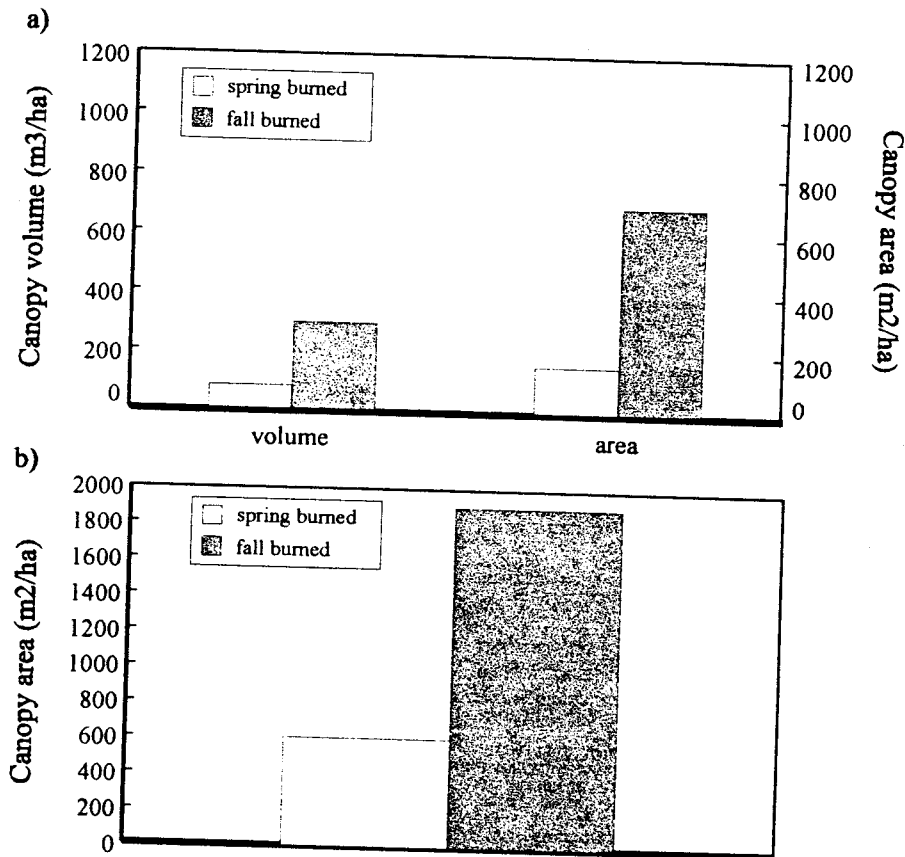


Figure 4: Canopy area was greater for *Rosa* spp. in 1997 (b) compared to 1996 (a). Canopy volume and area (a) was greater on spring burned sites in 1996, and for area in 1997 (b). Differences between seasons are significant ($p < 0.05$).

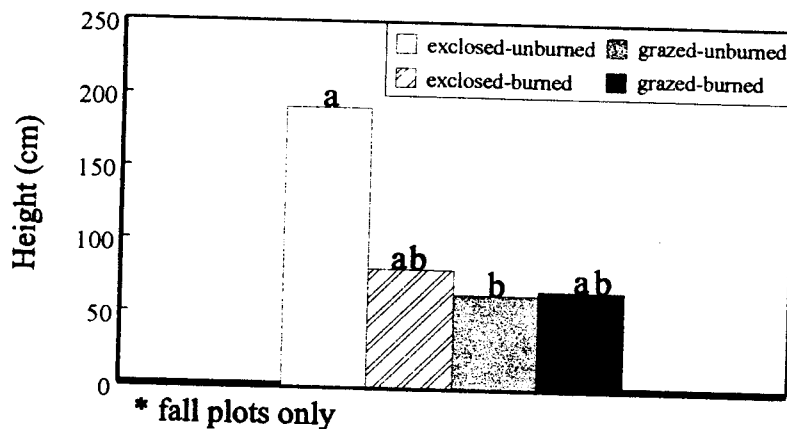


Figure 5: Height differences based on treatment for *Ulmus americana* in 1996. *Ulmus americana* was taller in plots protected from grazing and burning. Different letters denote significant ($p < 0.05$) differences.

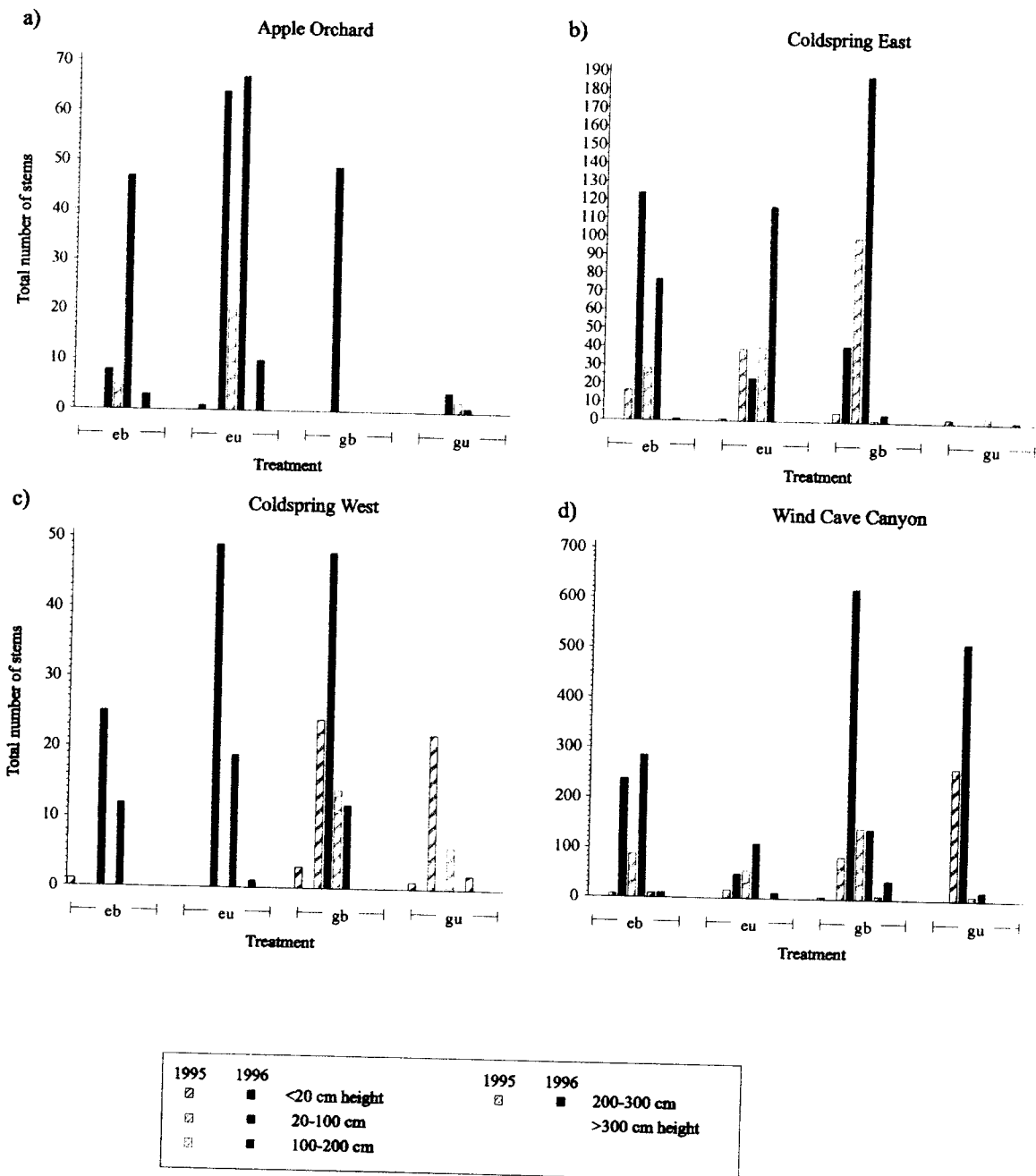


Figure 6: Histograms of total stem counts for elm (a-d) in several sites. Treatments: eb=exclosed-burned, eu=exclosed-unburned, gb=grazed-burned, gu=grazed-unburned.

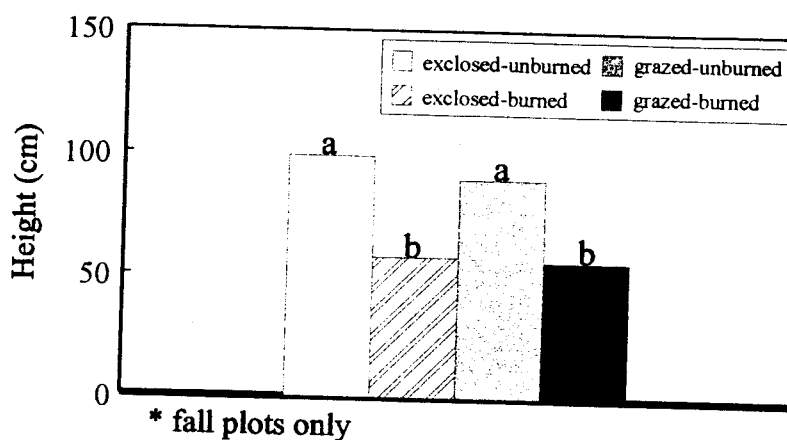


Figure 7: Burning temporarily reduced heights of *Ribes aureum* in 1996. Different letters denote significant ($p < 0.05$) differences.

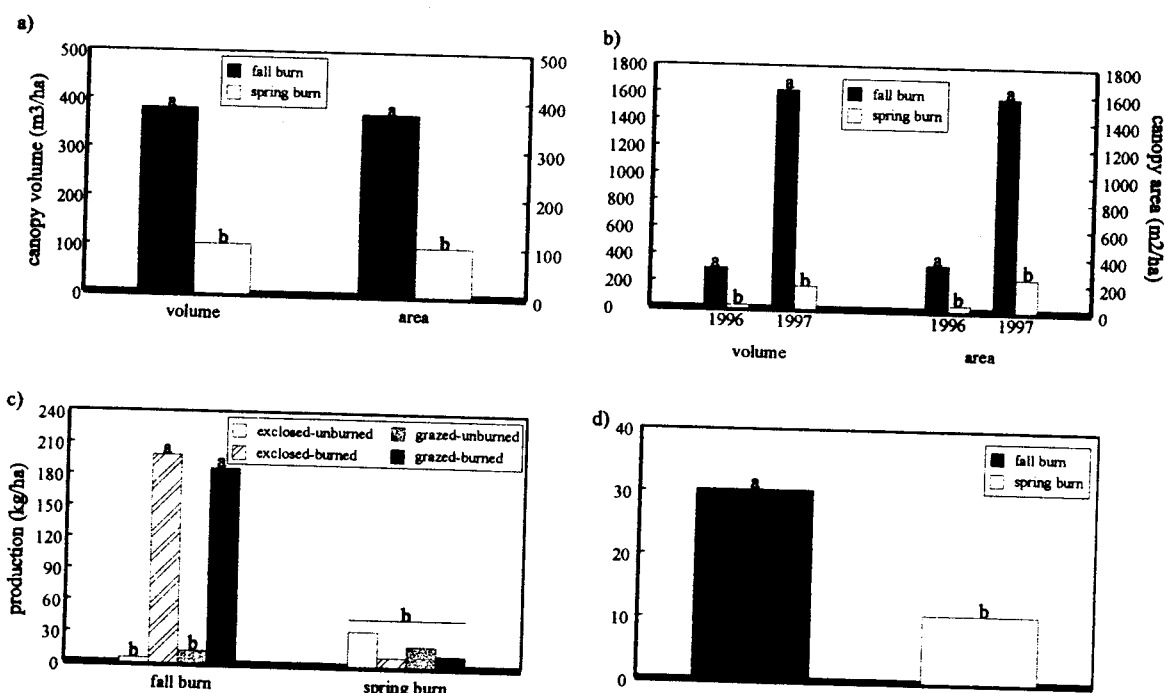


Figure 8: Pre-treatment (1995) (a) and post-treatment (b) canopy volume and area differences, and production differences in 1996 (c) and 1997 (d) for *Ribes aureum*. Different letters denote significant ($p < 0.05$) differences. Fall burning stimulated growth of *Ribes aureum*.

Acer negundo

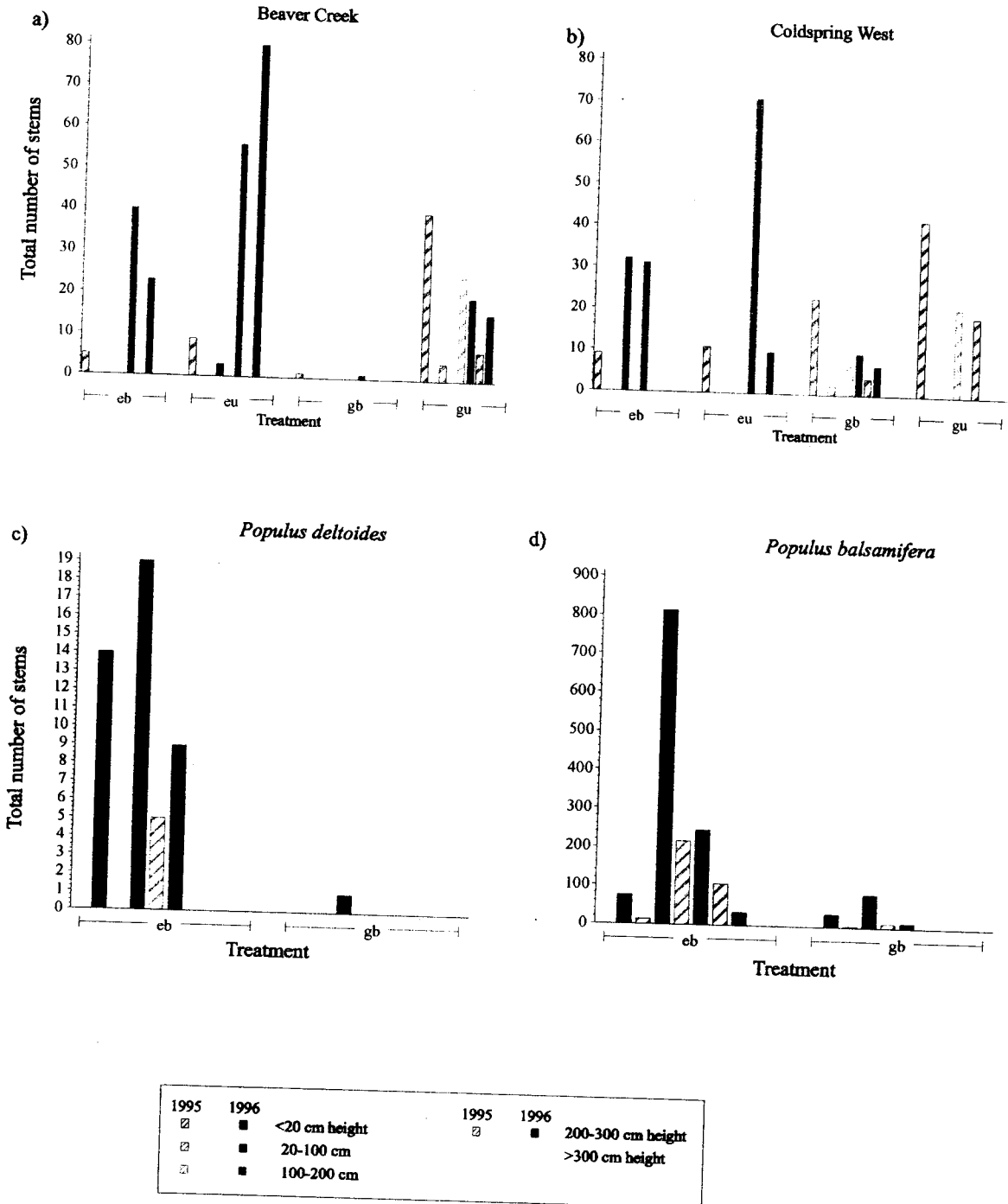


Figure 9: Histograms of total stem counts for boxelder (a-b) and for plains cottonwood (c) and black cottonwood (d) in the Black Cottonwood enclosure. Treatments: eb=exclosed-burned, eu=exclosed-unburned, gb=grazed-burned, gu=grazed-unburned.

Discussion

Prescribed burning can be a valuable management tool in the maintenance of many plant communities, particularly those which have evolved with high fire frequency, as historically occurred in the Black Hills region. Using prescribed fire to manage for increased shrub production in these riparian areas, however, may have mixed consequences. For example burning led to an increase in regeneration of species of interest, such as elm and box elder. However, reduction of, or protection from, herbivory may be the most important element in reaping long-term benefits of increased regeneration from burning. Statistical analyses found that by 1997, no significant differences in shrub production or canopy dimensions were evident between burned and unburned areas. Bock and Bock (1984) found similar responses of shrubs to prescribed fires in ponderosa pine forests of WCNP with shrub cover declining immediately following burns, but recovering after two years with no net increase as a result of burning. Bock and Bock (1983) specifically found decreases in height of *Ribes* spp. in the years immediately after burning as we did, but unlike this study, they found overall density decreases of *Ribes* spp. for several years after burning. Differences in our results may be due to the fact that we did not lump all *Ribes* spp. together, and that Bock and Bock encountered at least one different *Ribes* species in their burns.

Herbivory suppressed shrub canopy volume and area in 1996, and contributed to decreased height growth in elm. In general, herbivory rates on riparian shrubs of WCNP are low, however, winter percent leader use was greater on several species, including elm (38%), rose (35%), and willow (76%). Elk numbers were reduced just prior to the commencement of this study, and as a result, browsing pressure from 1995-97 may have been lower than in previous years. The increased use of burned areas by herbivores in the season immediately following fires indicates that if burning is to be used as a tool to manage for increased production in riparian communities, measures should be taken to alleviate browse pressure on newly regenerating plants. Many studies document increased use of burned areas by ungulates, particularly cervids, in a variety of habitats (Irwin 1975, Coppock and Detling 1986, Pearson et al. 1995). MacCracken and Viereck (1990) correlated increased use of shrubs by moose in Alaska to increased levels of proteins and minerals in browse species, but found these nutrient increases were short-lived. The drop in percent leader use by summer 1997 suggests that attraction to the burned areas in WCNP may be short-lived as well, but continued data collection would be necessary to prove this.

Fall burning had a significant impact on shrub production and regeneration immediately following burns. Overall canopy volume and area were significantly higher in riparian areas that were burned in fall compared to spring burning. However, height growth of some species, (e.g. *U. americana* and *R. aureum*) was suppressed by burning in fall, despite overall production or regeneration increases. Fall burning also had an advantage in that herbivore use of burned areas was not as high as when areas were burned in spring. When utilization by herbivores is suppressing plants, such as elm, and burning increases regeneration, burning regimes that result in heavier utilization should be avoided.

The combination of burning and herbivory also had a significant impact. Shrub canopy volume and area were lowest in the growing season immediately following burning, in areas that were both subject to burning and herbivory. Both burning and herbivory reduced heights of elm, though the combination did not result in greater suppression. Shrub productivity, canopy volume, and canopy area by 1997 were equivalent in exclosed areas over grazed-burned areas. However, if elk densities were greater, the heavier browsing could result in reduced shrub production and cover for longer periods following burns.

Prescribed burning can increase regeneration of some species of riparian shrubs in Wind Cave National Park, but measures must be taken to, at least temporarily, reduce browsing pressure on the regenerating plants. Several options could be used to achieve this goal:

- 1) Burned areas could be fenced prior to, or immediately following, burning.
- 2) Elk herds could be culled to lower densities prior to conducting burns to reduce browse pressure on regenerating plants.
- 3) Larger areas of mixed riparian, grassland, and pine forest could be burned to provide more forage areas for elk so they might not concentrate on small burned riparian patches.

The fires which were ignited for the purpose of this study in 1996 were tightly managed and consumed much less material than the escaped fire which burned the Beaver Creek and Coldspring East sites in 1997. This unplanned fire offers a unique opportunity to study the effects of a larger, hotter spring fire on grazed and ungrazed riparian communities. We would recommend that measurements at these sites continue so that some comparisons between the effects of the two types of fires on shrub production might be studied. There are still two sites which were burned in spring 1996 and were not affected by the 1997 fire which can be used for comparison. We believe that continuing research on these plots could yield additional, useful information to park managers since they plan to continue an aggressive program of prescribed burns throughout the park. We also recommend additional measurements at all our study sites several additional years hence to determine whether there are long-term impacts on shrub productivity as a result of the 1995-96 burns. Measurements in 2001 and 2002, for example, might reveal if recruitment into heights beyond the reach of elk had occurred.

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Literature Cited

- Bock, J.H. and C. E. Bock. 1983. *Some effects of fire on vegetation and wildlife in ponderosa pine forests of the southern Black Hills*. Unpublished final report. Department of Environmental, Population, and Organismic Biology, University of Colorado, Boulder, CO 80309. 58 pp.
- _____. 1984. Effects of fires on woody vegetation in the pine-grassland ecotone of the southern Black Hills. *American Midlands Naturalist* 112:35-42.
- Coppock, D.L. and J.K. Detling. 1986. Alteration of bison and black-tailed prairie dog grazing interaction by prescribed burning. *Journal of Wildlife Management* 50:452-455.
- Irwin, L. L. 1975. Deer-moose relationships on a burn in northeastern Minnesota. *Journal of Wildlife Management* 39:653-662.
- Jensen, C.H. and P.J. Urness. 1981. Establishing browse utilization from twig diameters. *Journal of Range Management* 34(2):113-116.
- MacCracken, J.G. and L.A. Viereck. 1990. Browse regrowth and use by moose after fire in interior Alaska. *Northwest Science* 64:11-18.
- Maguder, T.L. 1983. Wind Cave's riparian habitats. *South Dakota Digest* 52:21-23.
- Pearson, S.M., M.G. Turner, L.L. Wallace, and W.H. Romme. 1995. Winter habitat use by large ungulates following fire in northern Yellowstone National Park. *Ecological Applications* 5:744-755.
- Pitt, M.D. and F.E. Schwab. 1990. Assessment of a nondestructive method for estimating browse use. *Journal of Wildlife Management* 54(1):175-179.
- Shepardson, D.P. 1980. *The effect of moisture, wildlife utilization, and fire suppression on regeneration of uncommon trees and shrubs of Wind Cave National Park*. Wind Cave National Park, Hot Springs, South Dakota. 15 pp.
- Shilts, D. , R.W. Klukas, B.L. Freet, and T. Oliverius. 1980. *Fire management plan, Wind Cave National Park, Hot Springs, South Dakota*. 279 pp.
- Smith, J. 1978. *Rare tree and shrub survey in Wind Cave National Park*. Report to the Superintendent, Wind Cave National Park, Hot Springs, South Dakota. 17 pp.

