

Initial Study of Deciduous Woodlands and Thickets  
at Devil's Tower National Monument

Submitted to the National Park Service  
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## Introduction

Devil's Tower National Monument, located on the western flank of the Black Hills in northeastern Wyoming, contains deciduous woodlands and thickets common in the Black Hills but absent from other parts of the state. Woodlands on terraces of the Belle Fourche River have an open tree overstory of bur oak and green ash, often with a dense tall shrub layer dominated by chokecherry and hawthorn. Mesic draws support small groves of bur oak, green ash, and ponderosa pine growing above dense thickets of chokecherry, hawthorn, and plum. These deciduous woodlands have been described generally (McIntosh 1931, Olson and Gerhart 1982, Hoffman and Alexander 1987), but no specific descriptions are available for stands from the Monument.

In the spring of 1989, the National Park Service (NPS) began to study the effects of browsing by deer on this deciduous vegetation. As part of the study, NPS hired the Wyoming Natural Diversity Database (WNDDDB) of The Nature Conservancy to design and help implement a program to describe deciduous communities at the Monument and to monitor changes in those communities with protection from browsing. Staff from NPS and WNDDDB selected six sites representing the deciduous vegetation of the Monument, and NPS staff built an enclosure at each site. NPS and WNDDDB staff then collected vegetation data within each enclosure and in a nearby unfenced area. These data will provide a detailed picture of species composition, and of size-class structure of shrubs and trees, in deciduous woodlands and thickets on the Monument. The data also will establish a baseline condition for judging the effects of browsing. Vegetation will be sampled periodically at each of the six sites, with the unfenced sampling area serving as a control for the enclosure. Vegetation should change more within the enclosures than in the control areas if excluding browsing has any effect on the vegetation.

## Methods

### Data Collection

Six sites were chosen to represent the deciduous woodlands and thickets on the Monument (Figure 1). At each site in May 1989, NPS and WNDDDB biologists marked corners on two sampling areas, each approximately 10 meters square. The sampling areas at a site are within 20 meters of each other, and were selected to be as similar in shrub canopy cover, herbaceous understory cover, and species composition as possible. (Selection of sampling areas was arbitrary and based on visual survey of the vegetation.) In July 1989, NPS staff selected one of the sampling areas at each site by coin toss, and constructed a woven wire fence approximately 2.5 m tall to enclose that sampling area and a buffer 0.5 m wide on all sides of the sampling area. The

bottom of the woven wire rests on the ground, and the fence is held up by metal "T" posts.

NPS and WNDDDB staff collected vegetation data in the 12 sampling areas (6 exclosures and 6 controls) from August 3 through August 8, 1989. Canopy cover of trees and shrubs > 0.25 meter tall was estimated by the line intercept method (Schemnitz 1980), using ten 10-meter-long shrub lines per sampling area. We located the shrub lines in a stratified random manner, by designating one side of the sampling area as a baseline, dividing the baseline into ten 1-meter-long segments, and randomly choosing a point within each segment as the end of a shrub line. (Shrub lines were perpendicular to the baseline.) The length of the intersection of a shrub line with each tree or shrub canopy was recorded to the nearest centimeter. Openings less than 1 meter long were considered part of the canopy. We counted all the shrubs in each sampling area, and recorded dead shrubs separately from live. (Stems appearing to come from a common root system were considered an individual shrub, as were isolated single stems.) The diameter at breast height of every tree was measured, and each tree was recorded in one of the size classes shown in Table 1.

Cover of herbaceous species, shrubs < 0.25 meter tall, and seedlings of woody species was estimated in one hundred 20 cm x 50 cm herb plots in each sampling area. We located the herb plots by dividing each shrub line into ten 1-meter-long segments, and placing a corner of the herb plot at a randomly-chosen point within each segment. Cover of each species was estimated in a plot using the method of Daubenmire (1959), in which a polygon is described around the periphery of each canopy, and each species is assigned a cover class (rather than a percent cover estimate) based on the percentage of the plot covered by polygons of that species. We recorded cover values for the seven cover classes shown in Table 2.

Topographic position, aspect, and slope were recorded for each area, and the vegetation in the area was described qualitatively using The Nature Conservancy's standard plant community survey form (Appendix 2). Specimens of unknown plants were taken to the Rocky Mountain Herbarium at the University of Wyoming for identification.

#### Data Analysis

Mean percent cover and standard deviation of percent cover were calculated for each species, for total tall shrub and tree cover, and for total understory cover (herbs, low shrubs, and woody seedlings), in each exclosure and control. For a tall shrub or tree species, the lengths of that species's intercepts were summed line by line and the statistics calculated from the resulting ten values (i.e., from the species's cover on each of

ten lines). For total tall shrub and tree cover, the intercepts of all species on a line were summed and the statistics calculated from the resulting ten values (i.e., from total tall shrub and tree cover on each of ten lines). For an understory species, the cover value from each herb plot was converted to the midpoint of the corresponding cover range (Table 1), and the statistics calculated from the resulting 100 values (one per plot). For total understory cover, the cover of all species in a plot was summed for each plot and the calculations performed on the resulting 100 values.

The ratio (standard error of the mean, or sem)/(mean) was also calculated for each species, as a measure of the precision of the cover estimate. This ratio can be used to calculate a confidence interval for a cover estimate (Greig-Smith 1983), thus allowing a statement of the probability that two cover estimates from normally-distributed data are statistically different. A value of 0.1 or less for the ratio sem/mean often is taken in vegetation ecology as an indication of adequate sampling for a species (Knight 1978). The cover values for some of the species in this study were examined and found to be markedly non-normal, so the ratio sem/mean is used in this study only as an index of how extensively each species was sampled relative to other species.

In cases where a species had similar cover estimates for the control and exclosure at a site, and the species contributed substantial cover, the two estimates were compared using the Mann-Whitney two-sample test. This non-parametric statistical test indicates the probability that two estimates drawn from non-normally distributed data are statistically different. Estimates of total tall shrub and tree cover, and total understory cover, were also tested with the Mann-Whitney test. The Mann-Whitney test was used, rather than analysis of variance, because cover values for the herb plots are, in many cases, markedly non-normal and neither arcsine nor square-root transformation improved the non-normality. All calculations and statistical tests were performed with the SOLO Statistical System, Version 3.0(a) (BMDP Statistical Software, Los Angeles, CA).

## Results

### Sites 1 and 2

Sites 1 and 2 are in a bur oak - green ash (Quercus macrocarpa - Fraxinus pennsylvanicus) woodland on a terrace of the Belle Fourche River in the south-central part of the Monument, north of the seasonal housing and south of the paved road. The elevation at the sites is approximately 3870 feet. The trees grow in groves interspersed among openings dominated by western wheatgrass (Agropyron smithii) and pennycress (Thlaspi

arvense). Tree cover is less than 50%, with bur oak forming a tall, open canopy above a lower canopy of bur oak and green ash. Bur oak contributes more cover than does the ash. Chokecherry (Prunus virginiana) grows in dense patches beneath the trees. Edges of the chokecherry patches are sharp, and the shrubs have a sharp browse line approximately 1.5 meters above the ground. Exotic plants are ubiquitous in the understory, with Kentucky bluegrass (Poa pratensis) dominating the dense herbaceous layer.

Site 1 (Table 3) is in a relatively open part of the woodland. Exclosure 1 contains only one ash tree, and has only 25% tree cover. Shrubs are moderately dense. Kentucky bluegrass strongly dominates the understory, and houndstongue (Cynoglossum officinale) and pennycress are secondary species. Other herbaceous species and the low shrub snowberry (Symphoricarpos albus) are present in small amounts. The exclosure contains some leafy spurge (Euphorbia esula). Control 1 has less tree cover than does the exclosure, and contains no trees. Total tree and shrub cover is very similar in the two sampling areas, due to the greater amount of live shrub cover in the control. The control has roughly twice as many shrub stems. Understory cover is greater in the control, due mainly to the presence of Sprengel sedge (Carex sprengelii). Leafy spurge is present in the control stand.

Site 2 (Table 4) is in a part of the oak-ash woodland with more tree cover but no tall shrubs. Bur oak dominates exclosure 2, both in canopy cover and number of stems. Kentucky bluegrass strongly dominates the understory, where Sprengel sedge and houndstongue are secondary species. Control 2 differs only slightly from exclosure 2 in cover and composition of the overstory and understory.

### Site 3

Site 3 lies within a green ash woodland near sites 1 and 2, on a lower river terrace in the south-central part of the Monument at about 3850 feet elevation. Patches of green ash (with some bur oak) grow scattered among openings dominated by western wheatgrass, Kentucky bluegrass, cheatgrass (Bromus tectorum), hairy brome grass (B. commutatus), pennycress, and leafy spurge. Green ash forms a tree canopy above exclosure 3 (Table 5), and the exclosure contains three ash trees.

Chokecherry forms a moderately-dense tall shrub layer in the exclosure. Kentucky bluegrass and brome grass co-dominate the dense understory, and houndstongue and pennycress are secondary species. (The brome grass probably includes both cheatgrass and hairy brome. The grass was not flowering during data collection, and the two species are difficult to tell apart vegetatively.) Control 3 has more green ash overstory and a small amount of bur oak overstory, resulting in slightly more total tree canopy cover



than in the enclosure. Chokecherry shrubs are denser in the control, but the control and enclosure contain about the same amount of tall shrub canopy cover. Brome grass, pennycress, Kentucky bluegrass, and houndstongue are the principle understory species. Control 3 contains substantially less Kentucky bluegrass and considerably more pennycress than does the enclosure. The control also contains less total understory cover, although the understory is still quite dense. Leafy spurge is present in both the enclosure and control.

#### Site 4

Site 4 is in the bottom of a narrow east-facing draw in the northwestern part of the Monument. Ponderosa pine (Pinus ponderosa) forms an open tall tree overstory above a subcanopy of bur oak and green ash. Chokecherry and American plum (Prunus americana) form a patchy tall shrub layer above a dense herbaceous layer dominated by Sprengel sedge and blue wildrye (Elymus glaucus). An obvious line truncates the lower part of the tall shrub canopy, about 1.5 meters above the ground. Exotic species -- primarily Kentucky bluegrass, houndstongue, and smooth brome (Bromus inermis) -- are present, but contribute far less cover than in sites 1, 2, and 3.

Enclosure 4 has a tree overstory co-dominated by green ash and bur oak, with an open taller ponderosa pine canopy. American plum dominates the tall shrub layer, which contains some chokecherry. Sprengel sedge strongly dominates the understory, which contains Oregon grape (Mahonia repens), blue wildrye, and smooth brome as secondary species. The vegetation of control 4 is similar, although the control has less bur oak, less American plum, and less total tree and shrub cover. Trees are generally smaller in the control as well. The understory in the control has less Oregon grape cover and more Kentucky bluegrass cover than the enclosure understory, but the total understory cover is the same in the two sampling areas.

#### Site 5

Enclosure 5 and control 5 lie in a valley bottom at 3980 feet elevation in the north-central part of the Monument. Scattered boxelder (Acer negundo), bur oak, and green ash are present, but the tree overstory is sparse. Tall shrubs grow in dense thickets up to 500 m<sup>2</sup> in area. Chokecherry and American plum are the most common shrubs, and Crataegus columbiana var. chrysoarpa (hawthorn) and Viburnum lentago (nannyberry) are present. The sharp lower line of the tall shrub canopy and numerous dead shrub suckers suggest that the shrubs are heavily browsed.

Boxelder is the main tree species in a sparse overstory in enclosure 5 (Table 7). American plum dominates the tall shrub

layer, and chokecherry is a secondary species. Dead shrubs are common. Kentucky bluegrass strongly dominates the understory, Sprengel sedge and Oregon grape are secondary understory species, and numerous other herbs are present in small amounts. In control 5, nannyberry dominates the tall shrub layer, and hawthorn is the second most common shrub in the layer. Dead individuals of both species are abundant. The understory in control 5 is similar to the understory in the exclosure, with Kentucky bluegrass dominating, and Oregon grape and Sprengel sedge present as secondary species. Total understory cover is slightly less in the control.

Total tree and shrub cover is less in exclosure 5 and control 5 than at sites 1 through 6. Leafy spurge is present at site 5, although it was absent from the control sampling area.

#### Site 6

Site 6 is a woodland on the floodplain of the Belle Fourche River in the northeastern corner of the Monument. Elevation is approximately 3850 feet. The vegetation at site 6 is a bur oak - green ash woodland similar to the woodlands at sites 1 and 2, with bur oak providing slightly more canopy cover. Boxelder is present in the tree layer. Chokecherry dominates an open, patchy tall shrub layer, and some American plum is present. The understory is dense and weedy, with Kentucky bluegrass dominating strongly and patches of other exotics (especially cheatgrass, hairy bromegrass, leafy spurge, houndstongue, and pennycress) common.

Bur oak and boxelder co-dominate the tree overstory in exclosure 6, and only a small amount of green ash is present (Table 8). Chokecherry forms a rather sparse tall shrub layer. Kentucky bluegrass is a strong understory dominant, and blue wildrye, Oregon grape, houndstongue, leafy spurge, and green needlegrass (Stipa viridula) are present in significant amounts. Bur oak and green ash co-dominate the tree layer in control 6, and chokecherry forms an open tall shrub layer. American plum is present. Kentucky bluegrass dominates the understory strongly. Green needlegrass and slender wheatgrass (Agropyron trachycaulum) contribute more cover in the control than in the exclosure, and blue wildrye is less common in the control. Total understory cover is slightly less in the control than in the exclosure.

#### Discussion and Recommendations

The vegetation at all six sites is similar to the Fraxinus pennsylvanicus - Prunus virginiana community described by Hansen and Hoffman (1988) from the Custer National Forest of southeastern Montana and western South Dakota. According to those authors, green ash dominates the tree layer; chokecherry,

plum, and hawthorn form a tall shrub layer; and rose, currant, and snowberry form a low shrub layer. Sprengel sedge dominates the understory in stands in good condition, and wildrye, bedstraw, Kentucky bluegrass, and other species are present. Kentucky bluegrass dominates the understory in heavily-grazed stands, where Japanese brome (Bromus japonicus -- a species very similar to B. commutatus) is common. The species richness in the low shrub and herb layers is reduced in heavily-grazed stands.

Overstories of stands at Devil's Tower National Monument contain substantial amounts of bur oak, and thus differ from the stands described by Hansen and Hoffman (1988). Stands on the mesic terraces of the Belle Fourche River (represented by sites 1, 2, 3, and 6) can be considered typical of this community at the Monument: bur oak may contribute slightly more cover overall than does green ash, but ash frequently co-dominates patches of woodland. Boxelder may be present, but is at best a secondary species overall. Site 4 -- a narrow draw surrounded by ponderosa pine woodlands -- is also a mesic site, but is small enough that pines from the adjacent slopes form a tall tree canopy above the oak and ash. Site 5 lies at the edge of a broad, grassy valley bottom, and probably is the driest of the six sites. The tree canopy there is sparse. Most oak and ash in stands on the Monument are medium-sized trees, between 12 and 51 cm dbh. Oak seedlings were present in about half the sampling areas, but ash seedlings were rare or absent. Saplings of both species were rare.

All of the sites sampled in this study have tall shrub layers similar to the layer described by Hansen and Hoffman (1988). Chokecherry dominates most stands, and American plum is common. Hawthorn and nannyberry may be present, but are uncommon. The tall shrubs grow in patches, which may be so dense that travel through them is difficult. These shrub layers commonly have a sharp lower boundary, suggesting that they have been browsed. Dead shrubs often outnumber live shrubs, especially at site 5, where the shrubs are thickest. The low shrub layer described by Hansen and Hoffman (1988) is represented in the Monument stands by sparse snowberry and currant. Understories in most stands in the Monument are now dominated by exotic species, primarily Kentucky bluegrass, houndstongue, and brome grasses. The leading native understory species are Sprengel sedge, Oregon grape, and green needlegrass. Sprengel sedge dominates at site 4, where the understory has the lowest representation of exotics.

Woodlands on mesic sites at Devil's Tower usually have slightly more bur oak cover than green ash cover, but green ash is present in substantial amounts in nearly all stands. Consequently, the woodlands on the Monument should be considered stands of the Fraxinus pennsylvanicus - Prunus virginiana community, rather than stands of a Quercus macrocarpa community.

Woodlands with bur oak overstories are common in and around the Black Hills (Hoffman and Alexander 1987), but these oak woodlands contain little or no green ash, have large amounts of snowberry in the understory, and grow on hillsides.

Although the exclosure and control at each site are within 20 meters of each other, composition of the vegetation usually differs between the two sampling areas. This difference in vegetation over short distances illustrates the patchy nature of the green ash woodlands, and indicates that the 10 meter x 10 meter sampling areas are too small to average out the patches of vegetation. The differences between exclosure and control can be complex. At sites 1, 5, and 6, for example, total tree and tall shrub cover is similar in the exclosure and control, but species composition in the tree and tall shrub strata is quite different. Understories at these sites differ from exclosure to control more in composition than in total understory cover, since understories are dense in all sampling areas but the absolute amount of cover of individual species varies. Exclosure 3 and control 3 are similar in composition and total cover both in the tree and tall shrub layers and in the understory. Understories in exclosure 4 and control 4 are similar, but the tree and tall shrub strata differ markedly in amounts of bur oak and American plum. Exclosure and control at site 2 resemble each other closely in the understory and overstory.

Statistical tests of differences in cover -- even non-parametric tests like the Mann-Whitney test used herein -- have limited use in comparing vegetation between sampling areas. First, time usually is too short to obtain sample sizes large enough to give a small standard error for any but common species. The large ratios of (standard error of the mean)/(mean) for most species in tables 3 through 8 illustrate this point. Second, the relationship between statistically significant difference and ecologically significant difference is unclear. For example, Oregon grape has a mean cover of 12.07% in exclosure 4 and 5.60% in control 4. The probability of obtaining a difference this great is nearly zero, so the difference is clearly significant statistically. But the ecological significance of this difference can only be judged when the value of Oregon grape to wildlife, or its role in vegetation dynamics or some other ecological process, is known.

Statistical tests will, however, be useful in determining whether excluding browsing has any effect on the vegetation at the study sites. The important comparisons in this case will be between data sets collected from the same sampling area at different times. If excluding browsing has an effect on the vegetation, then statistically significant differences should exist between data sets from the same exclosures at different times. These differences should be larger than differences between data sets from the controls. Statistical differences

over time in the same enclosure, however, will only indicate that the vegetation has actually changed, and that the apparent difference is not just an artifact of sampling. The ecological significance of the differences will still be open to question.

#### Recommendations

The sampling procedure described above should, if carried out periodically, show changes in species composition of the controls and enclosures. One weakness in this procedure, however, is estimating cover of woody seedlings, rather than counting them. Counts of individual seedlings in the 20 cm x 50 cm herb plots would allow an estimate of density of the seedlings in the sampling areas, and give a better idea of changes in recruitment of seedlings.

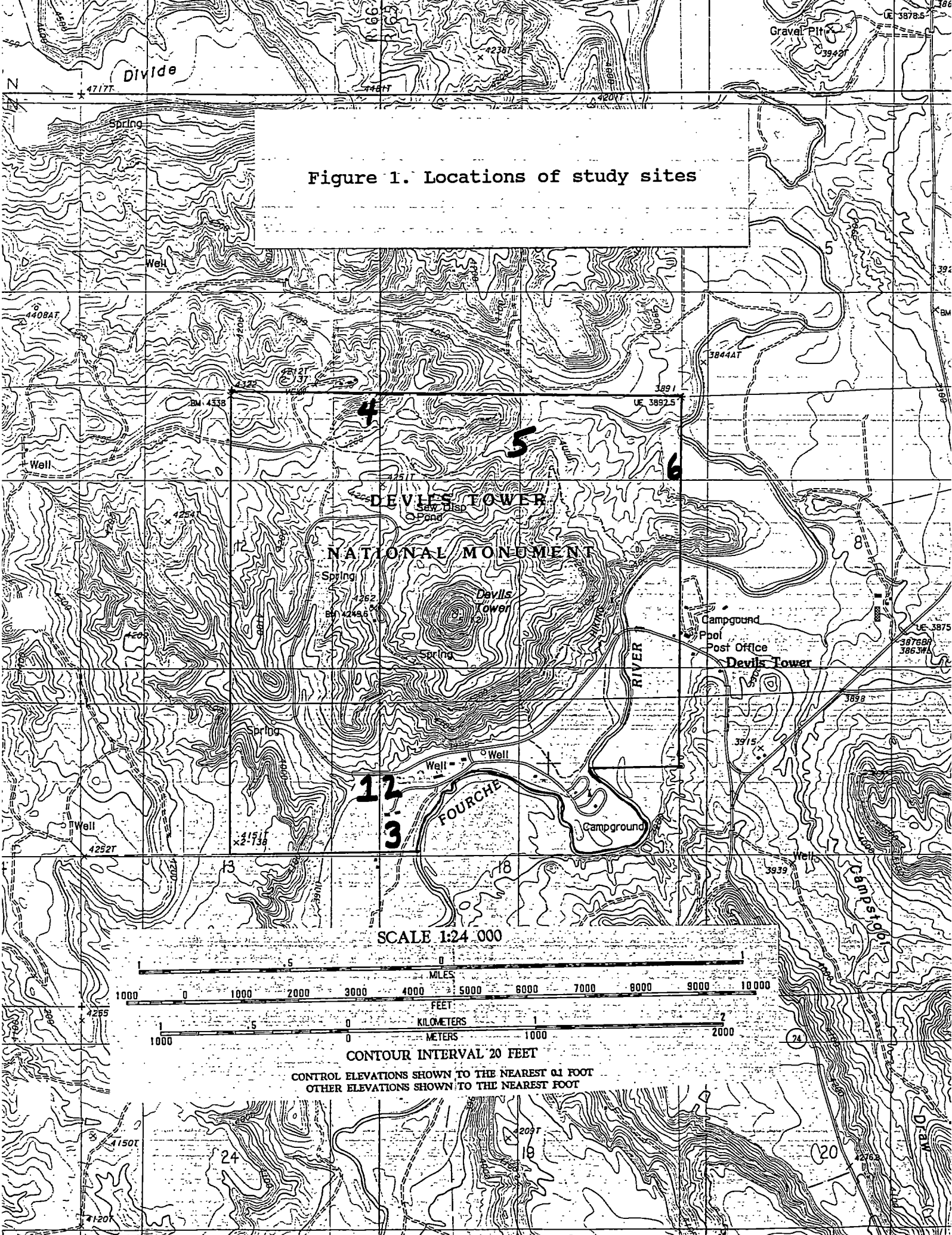
NPS and WNDDDB staff have discussed the need for periodic photographs of the controls and enclosures. These photos would show changes in physical structure of the shrub strata, thereby complementing the information on species composition available from the cover data.

Although the statistical tests useful for studying changes in vegetation are of limited use in comparing different sampling areas (as discussed above), the relationships between sampling areas can be investigated with such multivariate techniques as ordination. By calculating indices of similarity or dissimilarity from the cover data, ordination might show relationships between the sites which could help explain why vegetation changes at some of the sites over time, but not at other sites.

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Figure 1. Locations of study sites

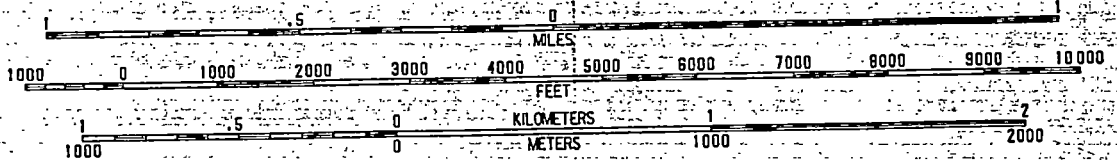


DEVILS TOWER  
NATIONAL MONUMENT

FOURCHE RIVER

3  
4  
5  
6

SCALE 1:24 000



CONTOUR INTERVAL 20 FEET

CONTROL ELEVATIONS SHOWN TO THE NEAREST 0.1 FOOT  
OTHER ELEVATIONS SHOWN TO THE NEAREST FOOT

Table 1. Size classes of trees by diameter at breast height (dbh)

<u>Size class</u>	<u>Range in dbh (cm)</u>
1	< 6, < 0.5 m tall
2	< 6, > 0.5 m tall
3	6 - 12
4	12 - 25
5	25 - 38
6	38 - 51
7	51 - 64
8	64 - 76
9	76 - 89
10	89 - 102
11	102 - 114
12	> 114

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Table 2. Cover classes used in estimating canopy cover of herbaceous species, low shrubs, and woody seedlings.

<u>Cover Class</u>	<u>Range in Percent Cover</u>	<u>Midpoint</u>
1	0-1	0.5
2	1-5	3
3	5-25	15
4	25-50	37.5
5	50-75	62.5
6	75-95	85
7	95-100	97.5



In the following tables, each species is denoted by six-letter acronym composed of the first three letters of the genus name and the first three letters of the species name. Appendix 1 lists the scientific names and common names associated with these acronyms. As note 2 in Appendix 1 explains, species were represented on the data sheets by four-letter acronyms, or by other notations.



Table 3 (continued). Vegetation at Site 1.

## HERBS, LOW SHRUBS, AND WOODY SEEDLINGS

Species	Exclosure 1				Control 1				Prob.
	AVE	STD	FRE	SEM	AVE	STD	FRE	SEM	
AGRTRA	0.18	1.53	2.00	0.85	0.04	0.31	3.00	0.77	
AMBPSI	0.00	0.05	1.00	1.00					
BRO SP					0.01	0.07	2.00	0.70	
CARHOO	0.44	3.77	3.00	0.86					
CARSPR					45.61	26.69	98.00	0.06	
CHEPRA	0.46	2.17	14.00	0.47	0.06	0.32	6.00	0.11	
CYNOFF	9.85	9.59	86.00	0.10	13.89	15.92	89.00	0.11	0.3345
DESSOP	0.04	0.31	3.00	0.77	0.01	0.05	1.00	1.00	
ELYGLA					0.15	1.50	1.00	1.00	
ERACIL	0.00	0.05	1.00	1.00					
EUPESU	1.11	4.74	11.00	0.43	0.63	2.64	10.00	0.42	
GAL SP					0.08	0.43	5.00	0.57	
HELANN	0.00	0.05	1.00	1.00					
MELOFF	0.21	0.72	12.00	0.34	0.06	0.32	7.00	0.53	
POAPRA	83.40	20.89	100.00	0.03	84.92	24.70	100.00	0.03	0.1903
PRUVIR	0.94	3.02	23.00	0.32	3.01	5.21	52.00	0.17	0.0002
QUEMAC	0.06	0.42	3.00	0.65					
STIVIR	0.18	1.53	2.00	0.85					
SYMALB	0.17	0.60	13.00	0.36	0.14	0.60	9.00	0.41	
THLARV	3.09	8.39	30.00	0.27	3.07	9.65	35.00	0.31	
Total	99.55	2.37	100.00	0.05	151.83	89.93	100.00	0.06	0.0000

AVE = Estimate of percent cover

STD = Standard error of percent cover

FRE = Frequency of occurrence

SEM = Ratio of Standard error of percent cover estimate  
Percent cover estimate

PROB = Probability (from Mann-Whitney test) of observed difference in mean cover

Table 4. Vegetation at Site 2

## TREES AND TALL SHRUBS

Species	COVER								
	Exclosure 2				Control 2				Prob.
	AVE	STD	FRE	SEM	AVE	STD	FRE	SEM	
FRAPENL	17.95	19.27	70.00	0.34	7.07	10.49	4.00	0.47	0.1509
FRAPEND	1.60	5.06	10.00	1.00					
QUEMACL	72.10	30.91	100.00	0.13	84.83	16.52	100.00	0.06	0.3447
QUEMACD	1.90	4.01	20.00	0.67	0.5	1.58	10.00	1.00	
Total	93.55	16.58	100.00	0.06	91.95	16.44	100.00	0.06	0.3643

DENSITY (# stems in 100 m<sup>2</sup> stand)Shrubs

NO SHRUBS	Exclosure 2		Control 2	
	<u>Small</u>	<u>Large</u>	<u>Small</u>	<u>Large</u>

Trees

	<u>Size Class</u>											
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>
	Exclosure 2											
FRAPEND			1									
QUEMACL				1	4	5	4					
QUEMACD				4								
	Control 2											
FRAPENL							1					
QUEMACL				1	5	5	4	2				
QUEMACD							1					

Table 4 (continued). Vegetation at Site 2

## HERBS, LOW SHRUBS, AND WOODY SEEDLINGS

Species	Exclosure 2				Control 2				Prob.
	AVE	STD	FRE	SEM	AVE	STD	FRE	SEM	
ACHMIL	0.36	2.14	4.00	0.60					
CARSPR	17.42	32.65	34.00	0.18	11.32	22.80	35.00	0.20	0.728
CHEPRA	0.05	0.31	5.00	0.63	0.50	2.20	12.00	0.44	
CYNOFF	15.56	14.63	98.00	0.09	14.23	16.00	88.00	0.11	0.127
GAL SP	1.05	2.73	28.00	0.26	0.19	0.72	9.00	0.37	
MELOFF	0.04	0.31	3.00	0.77	0.06	0.42	3.00	0.65	
POAPRA	77.57	29.37	99.00	0.00	78.96	27.3	99.00	0.03	0.941
PRUVIR	0.01	0.42	2.00	0.70					
QUEMAC	0.85	8.50	1.00	1.00	0.03	0.30	1.00	1.00	
STIVIR	0.01	0.05	1.00	1.00					
SYMALB	0.71	1.20	37.00	0.17	0.77	1.85	31.00	0.24	
THADAS	0.09	0.52	4.00	0.54	0.03	0.30	1.00	1.00	
THLARV	0.01	0.05	1.00	1.00	0.22	1.55	4.00	0.72	
Total	113.41	89.74	100.00	0.08	106.32	73.52	100.00	0.07	0.127

AVE = Estimate of percent cover

STD = Standard error of percent cover

FRE = Frequency of occurrence

SEM = Ratio of Standard error of percent cover estimate  
Percent cover estimate

PROB = Probability (from Mann-Whitney test) of observed difference in percent cover

Table 5. Vegetation at site 3

## TREES AND TALL SHRUBS

## COVER

Species	Exclosure 3				Control 3				Prob.
	AVE	STD	FRE	SEM	AVE	STD	FRE	SEM	
FRAPENL	39.13	32.11	80.00	0.26	66.48	24.42	100.00	0.12	0.0757
FRAPEND	6.10	8.31	40.00	0.43	3.85	5.74	40.00	0.47	
PRUVIRL	28.42	13.37	100.00	0.15	35.70	34.73	60.00	0.31	0.8798
PRUVIRD	14.63	16.61	70.00	0.36					
QUEMACL					8.80	18.70	20.00	0.67	
Total	88.28	23.54	100.00	0.08	114.83	31.22	100.00	0.09	0.0821

DENSITY (# stems in 100 m<sup>2</sup> stand)Shrubs

	Exclosure 3		Control 3	
	Small	Large	Small	Large
PRUVIRL	2	6	26	15
PRUVIRD		29	59	10

Trees

	<u>Size Class</u>											
	1	2	3	4	5	6	7	8	9	10	11	12
	Exclosure 3											
FRAPENL							2					1
	Control 3											
FRAPENL						2			1			

Table 5 (continued). Vegetation at site 3

## HERBS, LOW SHRUBS, AND WOODY SEEDLINGS

Species	Exclosure 3				Control 3				Prob.
	AVE	STD	FRE	SEM	AVE	STD	FRE	SEM	
AGRTRA	0.94	4.52	12.00	0.48	2.50	6.75	3.00	0.27	
BRO SP	49.72	40.28	84.00	0.08	38.61	41.61	4.00	0.11	0.0108
BROINE					2.28	13.84	5.00	0.61	
CALBUL	0.16	1.50	2.00	0.97					
CARSPR	1.68	10.58	5.00	0.63	3.56	15.13	6.00	0.42	0.5373
CHEBER	0.01	0.05	1.00	1.00	0.28	1.60	6.00	0.58	
CHEPRA	0.01	0.05	1.00	1.00	0.19	0.72	7.00	0.38	
CHOTEN	0.19	1.53	3.00	0.83					
COLLIN	0.01	0.05	1.00	1.00	1.09	3.60	8.00	0.33	
CYNOFF	21.85	25.24	87.00	0.12	20.58	22.86	10.00	0.11	0.7919
DESSOP	0.38	3.75	1.00	1.00	1.56	5.12	11.00	0.33	
ELYGLA	2.80	10.84	18.00	0.39	6.51	16.57	12.00	0.25	0.1329
EUPESU	0.03	0.30	1.00	1.00	0.30	1.62	13.00	0.54	
GAL SP	0.01	0.05	1.00	1.00	0.10	0.52	14.00	0.52	
HELANN	0.01	0.05	1.00	1.00					
KOCSCO	0.01	0.05	1.00	1.00	0.38	3.75	1.00	1.00	
MELOFF	0.04	0.30	2.00	0.87	0.01	0.05	16.00	1.00	
OPPLFC					0.01	0.05	1.00	1.00	
POAPRA	56.00	43.39	72.00	0.08	23.48	37.70	17.00	0.16	0.0000
POLCON	2.40	5.72	31.00	0.24	2.25	5.58	18.00	0.25	
PRUVIR	0.46	2.19	9.00	0.48	0.22	1.55	20.00	0.72	
QUEMAC					0.03	0.30	21.00	1.00	
SIS SP	0.03	0.30	1.00	1.00	0.06	0.42	2.00	0.70	
SYMALB	0.82	0.30	1.00	1.00	2.02	4.06	24.00	0.20	
TAROFF					0.15	0.66	25.00	0.44	
THLARV	13.69	24.01	59.00	0.18	33.13	31.88	27.00	0.10	0.0000
UNKNOWN	0.03	0.30	1.00	1.00	0.15	1.50	1.00	1.00	
Total	150.84	173.88	100.00	0.11	138.54	210.12	100.00	0.15	0.0508

AVE = Estimate of percent cover

STD = Standard error of percent cover

FRE = Frequency of occurrence

SEM = Ratio of Standard error of percent cover estimate  
Percent cover estimate

PROB = Probability (from Mann-Whitney test) of observed difference in percent cover

Table 6. Vegetation at site 4

## TREES AND TALL SHRUBS

## COVER

Species	Exclosure 4				Control 4				Prob.
	AVE	STD	FRE	SEM	AVE	STD	FRE	SEM	
FRAPENL	52.98	27.01	90.00	0.16	55.80	31.02	100.00	0.18	0.8703
FRAPEND	7.11	8.82	40.00	0.39	3.50	11.07	10.00	1.00	
PINPONL	10.72	11.71	50.00	0.35	20.00	14.68	80.00	0.23	0.1416
PRUAMEL	19.36	20.39	60.00	0.33	1.50	4.74	10.00	1.00	0.0275
PRUAMED	3.22	6.96	20.00	0.69	0.95	3.00	10.00	1.00	
PRUVIRL	5.63	11.68	20.00	0.63	5.55	5.88	60.00	0.34	0.3691
PRUVIRD					0.90	2.85	10.00	1.00	
QUEMACL	49.06	24.75	90.00	0.16	26.15	17.65	90.00	0.21	0.0412
Total	133.27	49.87	100.00	0.10	114.35	28.56	100.00	0.07	0.0494

DENSITY (# stems in 100 m<sup>2</sup> stand)Shrubs

	Exclosure 4		Control 4	
	Small	Large	Small	Large
PRUAMEL		4		
PRUVIRL		7	2	8
PRUSPPL	3		35	
PRUSPPD	7	25	64	35

Trees

	<u>Size Class</u>											
	1	2	3	4	5	6	7	8	9	10	11	12
	Exclosure 4											
FRAPENL				4	5	1						
FRAPEND	1				1							
QUEMACL				2	1	1						
	Control 4											
FRAPENL	1			8	5		1					
FRAPEND				1		1						
QUEMACL							2					



Table 6 (continued). Vegetation at site 4

## HERBS, LOW SHRUBS, AND WOODY SEEDLINGS

Species	Exclosure 4				Control 4				Prob.
	AVE	STD	FRE	SEM	AVE	STD	FRE	SEM	
ASTFLE					0.09	0.51	3.00	0.57	
BROANO					0.03	0.30	1.00	1.00	
BROINE	8.37	23.78	18.00	0.28	0.76	5.28	3.00	0.70	
CARSPR	77.12	31.93	96.00	0.04	73.26	29.07	97.00	0.04	
CHEPRA	0.01	0.05	1.00	1.00					
COLLIN					0.09	0.51	3.00	0.57	
CYNOFF	0.06	0.42	3.00	0.65	1.75	6.26	12.00	0.36	
DISTRA	1.01	9.75	2.00	0.97					
ELYGLA	5.95	12.73	52.00	0.21	9.85	17.97	76.00	0.18	0.0046
GALSP	0.75	2.65	22.00	0.36	0.99	1.86	53.00	0.19	
MAHREP	12.07	14.19	81.00	0.12	5.60	9.11	44.00	0.16	0.0000
ORYASP					0.63	6.25	1.00	1.00	
POAINT					0.01	0.07	2.00	0.70	
POAPRA	0.65	6.25	2.00	0.95	14.88	30.16	30.00	0.20	0.0006
PRUSPP					0.03	0.30	1.00	1.00	
PRUVIR	0.13	0.59	6.00	0.46	0.62	3.80	14.00	0.62	
RIBSP	0.15	1.50	1.00	1.00	0.01	0.09	3.00	0.57	
SMISTE	0.22	0.77	8.00	0.36	0.04	0.30	2.00	0.87	
SYMALB	1.18	9.76	8.00	0.82	0.09	0.52	4.00	0.54	
TAROFF					0.03	0.30	1.00	1.00	
THADAS					0.04	0.30	2.00	0.87	
UNKNOWN					0.22	0.77	8.00	0.36	
Total	107.67	37.88	100.00	0.04	108.99	43.94	100.00	0.04	0.5008

AVE = Estimate of percent cover

STD = Standard error of percent cover

FRE = Frequency of occurrence

SEM = Ratio of Standard error of percent cover estimate  
Percent cover estimate

PROB = Probability (from Mann-Whitney test) of observed difference in percent cover

Table 7. Vegetation at site 5

## TREES AND TALL SHRUBS

Species	COVER								Prob.
	Exclosure 5				Control 5				
	<u>AVE</u>	<u>STD</u>	<u>FRE</u>	<u>SEM</u>	<u>AVE</u>	<u>STD</u>	<u>FRE</u>	<u>SEM</u>	
ACENEGL	9.15	12.91	40.00	0.45					
ACENEGD	0.80	2.53	10.00	1.00					
CRACOLL	0.50	1.58	10.00	1.00	16.23	13.30	90.00	0.26	
CRACOLD	14.81	15.24	80.00	0.33	2.95	9.33	10.00	1.00	
FRAPENL					1.90	5.67	20.00	0.94	
PRUAMEL	37.88	23.95	100.00	0.20	0.85	1.89	20.00	0.70	
PRUAMED	9.17	14.56	50.00	0.50					
PRUVIRL	11.10	15.33	60.00	0.44	7.70	20.48	20.00	0.84	0.1736
PRUSPPD	37.00		10.00						
QUEMACL	0.70	1.89	20.00	0.85	3.45	6.53	30.00	0.60	
VIBLEND					2.25	4.20	30.00	0.59	
VIBLENL					35.93	34.68	70.00	0.31	
Total	75.95	24.66	100.00	0.10	83.12	31.70	100.00	0.12	0.4057

DENSITY (# stems in 100 m<sup>2</sup> stand)Shrubs

	Exclosure 5		Control 5	
	<u>Small</u>	<u>Large</u>	<u>Small</u>	<u>Large</u>
CRACOLL		1	3	14
CRACOLD		12	4	63
PRUAMEL		25		
PRUVIRL		5		2
PRUVIRD				1
PRUSPPL	17			
PRUSPPD	7	105		
VIBLENL			22	12
VIBLEND			24	32

Trees

	<u>Size Class</u>											
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>
	Exclosure 5											
ACENEGL					1							
QUEMACL							1					
	Control 5											
QUEMACL				1								
QUEMACD						1						

Table 7 (continued). Vegetation at site 5

## HERBS, LOW SHRUBS, AND WOODY SEEDLINGS

Species	Exclosure 5				Control 5				Prob.
	AVE	STD	FRE	SEM	AVE	STD	FRE	SEM	
ACHMIL	1.64	5.29	17.00	0.32					
AGRSMI	0.16	1.50	2.00	0.97					
AGRTRA					0.42	2.18	6.00	0.52	
ASTFLE	0.27	1.60	5.00	0.59					
CARSPR	13.35	25.82	33.00	0.19	9.29	21.76	33.00	0.23	0.7378
CHEBER	0.09	0.51	3.00	0.57					
CHEPRA	0.03	0.30	1.00	1.00	0.04	0.13	7.00	0.37	
COLLIN	0.03	0.30	1.00	1.00					
CRACOL					0.03	0.30	1.00	1.00	
CYNOFF	5.09	8.61	56.00	0.17	0.47	1.04	23.00	0.22	0.0000
ELYGLA	0.08	0.43	5.00	0.57	0.08	0.43	5.00	0.57	
EUPESU	1.63	6.12	12.00	0.38					
GAL SP	0.36	0.90	22.00	0.25	0.46	1.04	22.00	0.23	
HRYGRA					0.01	0.05	1.00	1.00	
KOCSKO					0.01	0.05	1.00	1.00	
MAHREP	21.30	17.89	82.00	0.08	20.05	19.18	94.00	0.10	0.5445
MELOFF	0.03	0.30	1.00	1.00					
NEPCAT	0.09	0.52	4.00	0.54					
POAPRA	93.60	17.71	97.00	0.02	94.00	9.61	100.00	0.01	0.2468
POLCON	0.01	0.05	1.00	1.00					
PRUSPP	0.44	2.17	11.00	0.49	0.01	0.05	1.00	1.00	
PRUVIR					0.30	1.62	6.00	0.54	
RIB SP	0.01	0.05	1.00	1.00	0.03	0.30	1.00	1.00	
SMISTE	0.18	1.53	2.00	0.85					
STIVIR					0.30	2.11	2.00	0.70	
SYMALB	0.50	3.78	5.00	0.76	0.98	3.03	24.00	0.31	
THADAS	0.06	0.42	3.00	0.65	0.01	0.05	1.00	1.00	
TRADUB	0.03	0.30	1.00	1.00	0.06	0.42	2.00	0.70	
VIBLEN					0.17	0.66	8.00	0.40	
VIO SP					0.01	0.07	2.00	0.70	
UNKNOWN					0.01	0.05	1.00	1.00	
Total	136.67	86.37	100.00	0.06	126.76	64.61	100.00	0.05	0.0143

AVE = Estimate of percent cover

STD = Standard error of percent cover

FRE = Frequency of occurrence

SEM = Ratio of Standard error of percent cover estimate  
Percent cover estimatePROB = Probability (from Mann-Whitney test) of observed difference in  
percent cover

Table 8. Vegetation at site 6

## TREES AND TALL SHRUBS

Species	COVER								Prob.
	Exclosure 6				Control 6				
	<u>AVE</u>	<u>STD</u>	<u>FRE</u>	<u>SEM</u>	<u>AVE</u>	<u>STD</u>	<u>FRE</u>	<u>SEM</u>	
ACENEGL	26.89	28.72	50.00	0.34					
FRAPENL	3.40	10.75	10.00	1.00	20.67	16.01	90.00	0.24	
FRAPEND	8.00	11.36	40.00	0.45					
PRUAMEL					1.10	3.48	10.00	1.00	
PRUAMED					0.54	1.71	10.00	1.00	
PRUVIRL	23.26	16.82	90.00	0.23	24.71	20.15	80.00	0.26	0.8798
PRUVIRD	3.33	7.94	20.00	0.75					
QUEMACL	32.89	24.28	80.00	0.23	37.44	29.12	100.00	0.25	1.00
Total	89.77	29.68	100.00	0.10	92.46	46.79	100.00	0.16	0.8798

DENSITY (# stems in 100 m<sup>2</sup> stand)Shrubs

	Exclosure 6		Control 6	
	<u>Small</u>	<u>Large</u>	<u>Small</u>	<u>Large</u>
PRUAMEL				1
PRUAMED				3
PRUVIRL		7		7
PRUVIRD	1	4		5

Trees

	<u>Size Class</u>											
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>
	Exclosure 6											
ACENEGL				1					1			
FRAPENL				1								
QUEMACL						3		1				
	Control 6											
FRAPENL				3					1			
QUEMACL						1		1				

Table 8 (continued). Vegetation at site 6

## HERBS, LOW SHRUBS, AND WOODY SEEDLINGS

Species	Exclosure 6				Control 6				Prob.
	AVE	STD	FRE	SEM	AVE	STD	FRE	SEM	
ACHMIL					0.03	0.30	1.00	1.00	
AGRSMI					1.25	4.94	10.00	0.40	
AGRTRA	0.16	1.50	2.00	0.97	2.45	6.02	24.00	0.25	0.0069
ARTCAN					0.15	1.50	1.00	1.00	
BRO SP	0.19	1.53	3.00	0.83	2.10	6.82	30.00	0.33	0.0010
CAMMIC	0.01	0.05	1.00	1.00	0.01	0.07	2.00	0.70	
CARSPR	0.63	2.96	5.00	0.47					
CHEPRA	0.07	0.33	9.00	0.47	0.06	0.42	3.00	0.65	
CYNOFF	2.93	4.67	67.00	0.16	0.01	0.05	1.00	1.00	
DESSOP	0.03	0.30	1.00	1.00					
ELYGLA	7.11	15.60	44.00	0.22	1.10	4.73	14.00	0.43	0.0001
EUPESU	3.66	10.91	22.00	0.30	0.28	1.60	6.00	0.58	
GAL SP	0.08	0.43	6.00	0.54					
LAC SP	0.03	0.30	1.00	1.00					
MAHREP	6.71	11.10	48.00	0.17					
MELOFF	0.04	0.30	2.00	0.87	0.03	0.30	1.00	1.00	
POAPRA	91.10	16.44	99.00	0.02	94.43	9.32	100.00	0.01	0.4613
PRUVIR	0.09	0.51	3.00	0.57	0.06	0.42	3.00	0.65	
QUEMAC	0.03	0.30	1.00	1.00					
STIVIR	2.20	10.19	11.00	0.46	8.57	17.08	43.00	0.20	0.0001
SYMALB	0.31	0.90	11.00	0.30	0.04	0.31	3.00	0.77	
TAROFF	0.06	0.42	2.00	0.70					
THADAS	0.01	0.05	1.00	1.00					
VICAME	0.01	0.05	1.00	1.00	0.01	0.05	1.00	1.00	
Total	115.38	78.44	100.00	0.07	110.36	52.01	100.00	0.05	0.0596

AVE = Estimate of percent cover

STD = Standard error of percent cover

FRE = Frequency of occurrence

SEM = Ratio of Standard error of percent cover estimate  
Percent cover estimate

PROB = Probability (from Mann-Whitney test) of observed difference in percent cover