Population Biology of Big Bluestem, *Andropogon gerardii*, in Open Space and Mountain Parks

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Abstract: Big bluestem, *Andropogon gerardii*, is one of the dominant grasses of North American tallgrass prairie, and a diagnostic feature for tallgrass prairie in Boulder County. Long-term studies of big bluestem populations ("plots") were established in the Open Space and Mountain Parks in 1995 and 1996. These plots consist of three replicates in ungrazed, winter- and summer-grazed areas, and high areas (close to the altitudinal limit of the species, ungrazed). Plant size features, seed production and vegetative area were compared under the different plot conditions. Plants flowered and set seed most vigorously under winter grazing..

Objectives and Hypothesis To compare the success of populations of big bluestem *Andropogon gerardii* in Mountain Parks and Open Space under different management regimes.

Major null hypothesis: Big bluestem populations are insensitive to land use treatment, annual variation and the interaction of the two.

Description of Methods

Plots were established in 1995 and 1996 based on the permanent grassland transects of Jane and Carl Bock. Plots are 10 x 10 meter squares, oriented EW/NS so that locating one corner is sufficient to define the entire plot. Directions for all plots are given in Table 1.

Table 1. Plot Locations

Bock Plot Number	Description of Plot Location	Finding Plot from Bock Marker
7	S of road to Boulder Valley Ranch	Plot surrounds marker: goes 2 m N,8 m S, 4 m E, 6 m W
28	Boulder Greens Venture, Shanahan Ridge	Marker is SW corner of plot
36	Bobolink Trail Gebhard (South Boulder Creek trail area)	Marker is SW corner of plot
45	Church WildlifeTransect (W of Cherryvale, S of Turnpike)	Marker is on the west edge of the plot, 4 m lie S of marker, 6 north
52	Davidson Mesa	Plot is in same pasture as marker but orients to the fence line: it is 3 m N, 3 m W of the second post, running N & W
57	Open Space Maintenance, grazing exclosure	Marker 57 is in the same half of the exclosure as the plot, but the plot orients on the fence: about 100 m from NW corner of exclosure: 8.4 m E of 20th fence post (counting all types of posts), or, 9.8 m. at 300° from 7th wooden fence post. Plot runs 10 m E and 10

		S of that spot.
58	Sans Souci Trailer Park Site 3 Exclosure	Plot begins 4 m W of pole, runs 7 m S, 3 m N (& 10 m W)
61	Flatirons Vista Wildlife Transect	Marker is NW corner of plot
102	Chataqua Park Meadow	Plot begins 3 m N of Bock marker, runs 7 m S, 3 m N (10 m W)
FS	Flagstaff Summit	long thin plot on sloping hillside: on Ute Trail above (lower, N side of road) parking lot plot is just above the first place that the trail goes so far N you can see out over the slope northward. The plot is on the ridge just E of that spot in the trail (uphill and slightly N, beginning with a relatively young mature pine and going 13 m S and 13 m W (much space without A. gerardii). There's a permanent aluminum tag nestled close to the pine tree.
BW	Betasso Water Treatment Plant	Plot is up the two-tire track that continues E (and S relative to the Loop Trail) of the picnic table at the E entrance to the Loop Trail. At the crest of the hill is an open area with 5 pines in the curve of the trail as it turns more N and then more E. From the NE most tree close to the trail, the plot is 6 m due E. From there it runs 6 m S, 4 m N(& 10 m. E). There's a permanent aluminum tag nestled close to the pine tree.
BM	Bald Mountain Summit	From the bench at the summit, the plot is centered on the first pair of pine trees down slope to the E. Beginning 2 m N of the tree, the plot is 9 m N, 5 m W (or 10 W but the far 5 lack A. gerardii). 5 m S of the reference point at the tree, plot begins again: it runs 10 m S, 2 m. E, 8 m W of the starting point. There's a permanent aluminum tag nestled close to the tree.

Plots were remapped in July of 1997. Plant vigor, as height of foliage and flowering stalks, and presence of flowering stalks, was recorded. Seed mass was collected at the end of the field season and seed weight and number of filled and unfilled seed will be determined during the winter of 1997-8. Maps of the plot are being digitized into ArcView (a geographic information system): by spring of 1998 all will be digitized and the previous years integrated.

Most plots were successfully harvested in September 1997, but a few were still flowering at that time. Because of the October snowstorm, those were not collected until November 24-26 1997.

Data collection (seed numbers and weights) from 1996 was completed by April 1997 and seeds were returned to the plots in May before *A. gerardii* 's growing season began.

Results

Throughout the discussion that follows, summary statistics are suspect because in most cases the extremes of the management treatment are significantly different from each other. In the case of ungrazed plot 102 (Chataqua Park) that is very reasonable since it alone was burned, but for the others the explanation is not so obvious. Interactions are not addressed in this report because there are at most three years of data available, a very small sample size for using time as a variable, and in fact most plots were set up in 1996 and have not yet been completed for 1997, so data for analysis of interactions is totally inadequate at this time.

Treatments differed significantly in most of the variables measured. High elevation plants had significantly shorter leaves (Table 2). Leaves in the ungrazed sites were significantly longer (Table 2). Plant canopy height (highest point, flowering or not) as significantly greatest (96.1 cm) in winter grazed, significantly less in ungrazed (61.3) and least in high elevation (46.2). (Data on plant height was not collected for summer grazed).

Table 2. Leaf Width and Leaf Height by Treatment

Leaf width measured in mm. on widest leaf, at widest point. Values from 1996.

Means with a different letter are statistically significantly different at the 5% level (t-test).

	Leaf Width			Leaf Height		
Treatment	*Mean*	*Std. dev.*	*N*	*Mean*	*std. dev.*	*N*
Summer-grazed	6.64 **a**	1.09	22	25.24 **a**	5.12	21
Winter - grazed	6.56 **a**	1.90	144	23.20 **a**	6.58	136
Ungrazed	6.70 **a**	1.25	47	29.19 **b**	8.21	47
High elevation	5.94 **b**	1.12	97	23.60 **a**	5.39	124

Table 3. Plant Height by Treatment (1996)

Means with a different letter are statistically significantly different at the 5% level (t-test).

Treatment	*Mean*	*std. dev.*	*N*
Winter - grazed	96.10 **a**	48.91	62
Ungrazed	61.35 **b**	27.66	49
High elevation	46.25 **c**	21.52	93

The flowering effort was greatest in winter grazed and ungrazed, least in summer grazed and high elevation, when measured as percent of the plants flowering (Table 4, Appendix 1).

Table 4. Per Cent Flowering by Treatment and Year.

By-plot data presented in Appendix 1.Means with a different letter are statistically significantly different at the 5% level (t-test).

	1995			1996		
Treatment	*Number Flowering*	*Total Plants*	*Per cent*	*Number Flowering*	*Total Plants*	*Percent Flowering*
Summer-grazed	*			33	111	29.7 **a**
Winter - grazed	181	397	45.6	145	228	63.6 **b**
Ungrazed	0	39	0	60	103	58.2 **b**
High elevation	*			61	149	40.9 **a**

* Plots not established in 1995.

Measured as seed mass production, winter grazed was significantly greater than ungrazed which significantly greater than the high elevation sites, with summer grazed flowering having the lowest mean seed mass production, but not being significantly different from ungrazed or high elevation (Table 5, Appendix 2).

Table 5. Seed Production by Treatment and Year.

Mass of seed production (including caryopsis, excluding stalks) in grams. By-plot data is given in Appendix 2. Means with a different letter are statistically significantly different at the 5% level.

	1995			1996		
Treatment	*Mean*	*std. dev.*	*N*	*Mean*	*std. dev.*	*N*
Summer-grazed	*			0.06 **ac**	0.12	104
Winter - grazed	1.30 **a**	4.19	392	4.37 **b**	14.57	235
Ungrazed	0.00 **a**	0.00	39	1.02 **a**	4.97	100
High elevation	*			0.11 **c**	0.27	150

* Plots not established in 1995.

The total number of good seeds, that is filled seeds as opposed to empty caryopses, was significantly greater for winter grazed. Ungrazed had the second highest mean but was not distinguishable from other plots due to its variation (see Appendix 3), and summer grazed and high elevation had statistically significantly the fewest seeds.

Table 6. Number of good seeds produced, by treatment and year.

By-plot data in Appendix 3. Means with a different letter are statistically significantly different at the 5% level.

	1995			1996		
Treatment	*Mean*	*std. dev.*	*N*	*Mean*	*std. dev.*	*N*
Summer-grazed	*			0.13 **a**	1.08	104
Winter - grazed	13.25 **a**	62.12	361	60.09 **b**	16.69	236
Ungrazed	0.00 **a**	0.00	39	25.11 **ab**	196.44	100
High elevation	*			0.15 **a**	0.78	150

* Plots not established in 1995.

Comparing good seeds to flowering effort as percent good seeds (percent of the seed mass that was filled seeds), winter grazed is statistically significantly greater than ungrazed, which is significantly greater than summer-grazed and the high elevation sites (Table 7).

Table 7. Percent of total seeds that were good seeds, by treatment and year.
By-plot data is given in Appendix 4. Means with a different letter are statistically significantly different at the 5% level.

	1995			1996		
Treatment	*Mean*	*std. dev.*	*N*	*Mean*	*std. dev.*	*N*
Summer-grazed	*			0.70 **a**	1.89	26
Winter - grazed	0.01 **a**	0.003	358	12.40 **b**	14.09	141
Ungrazed	0.00 **a**	0.00	33	4.06 **c**	8.07	57
High elevation	*			0.60 **a**	2.32	65

* Plots not established in 1995.

Plant size was greater in summer grazed and ungrazed treatments, least in winter grazed. This result is preliminary, since when the ArcView maps are done, accurate areas will be calculated from the maps (see figures). Also, while plant sizes may he comparision may indeed be greater in summer and ungrazed, it may be a product of recruitment rates rather than growth of clones: winter grazed has 411 plants as compared with 107 in ungrazed. When the ArcView maps are done I will be able to address this question.

Table 8. Size of plants compared by treatment .
By plot data in Appendix 5. Means with a different letter are statistically significantly different at the 5% level.

Treatment	Mean	std. dev.	N
Summer-grazed	3728.2 **a**	8173.0	106
Winter-grazed	1706.4 **b**	4464.4	411
Ungrazed	3774.2 **a**	9874.7	107
High elevation	1769.4 **ab**	7610.2	150

Correcting for the size of the plants, winter grazed had by far the greatest seed production per unit area, but a high variance so that it was statistically significantly different only from the high elevation plots which were the least productive (Table 9, Appendix 6).

Table 9. Seed production/square cm of plant, compared by treatment.
By plot data in Appendix 6. Within a year, means with a different letter are statistically significantly different at the 5% level.

	1995			1996		
Treatment	*Mean*	*std. dev.*	*N*	*Mean*	*std. dev.*	*N*
Summer-grazed	*			<0.0001 **ac**	0.001	99
Winter-grazed	0.010 **a**	0.051	358	0.378 **ab**	2.138	215
Ungrazed	0.00 **a**	0.000	33	0.008 **b**	0.024	94
High elevation	*			<0.001 **c**	0.001	150

*Plots not established in 1995.

Contribution of the Research to the Needs of Mountain Parks and/or Open Space Department

This study clearly shows that the management on the site dramatically affects the vigor of big bluestem. Big bluestem is an important species for the Open Space in itself, and can be used as an indicator of the health of the tallgrass prairie ecosystems in the Open Space and Mountain Parks.

The differences in leaf width are readily interpretted: high elevations are stressful environments not favoring vigorous growth of leaves, and the vegetation in ungrazed is taller requiring taller leaves on the grasses. Vegetative production has not been measured directly (i.e., by clipping) but plant height is an indicator of total biomass produced.

Seed production of big bluestem is dramatically changed by grazing practices. On the one hand summer grazed do not flower much or set many seed (Tables 4, 5,6, 7 and 9). Observation of the plots suggests that the effect of grazing is to suppress and retard flowering (Table 4). In addition there may be insufficient pollen of this wind-pollinated grass in the air over well-grazed pastures for those plants that put out stigmas to receive adequate amounts of pollen for much seed set.

The ungrazed site plants do not flower much either, but it cannot be because of loss of biomass. Arguing from other studies (e.g. Collins and Wallace 1987) the heavy plant cover impedes flowering. Plot 102 seems to support that, since although it is ungrazed, in

1996 it was burned and had the largest flowering effort recorded (Appendix 3). (The number of good seeds per plant is a function of chromosome number and plant size: in plot 102 the big plants have 90 chromosomes and as a result, a reduced number of filled seeds (Norrmann, Quarín and Keeler 1997, Appendix 7.)

The high elevation plots were chosen to be at the edge of big bluestem's elevational distribution. They show poor production, but this experiment was not designed to see what the causes of poor growth are but rather documents poor growth at the edge of the range.

The size of plants presented here were determined by measuring two diameters for the plant (at right angles) and assuming a rectangular shape. This is a valid comparision if there are no differences in shape between sites. This approach finds that summer grazed and ungrazed are significantly larger. However, there are many more plants (411!) in the in the winter grazed plots than in the other treatments, so more needs to be known to interpret this. If the winter grazed are seeding in faster, large plant size should not be taken to reflect a healthier population.

Accurate areas based on the maps (Figures 1-8) will be generated from the ArcView maps when those are complete (probably all digitized January 1998, all errors corrected by the end of March). Further statistical analysis, using StatView (1994) and ArcView (1996) will be carried out to look at interaction terms and the geographic differences in the plots.

In summary, winter grazed was consistently better for *A. gerardii* flowering and seed production. Or, more importantly, summer grazed and the high elevation sites (which are not grazed) were very low in seed production, producing less than a seed per plant in 1996.

The population biology of *Andropogon gerardii* is not very well known despite its importance (e.g. Keeler et al. 1987, Reichman 1987). Much work has been done on productivity and response to fire and drought of the species (e.g. Weaver and Fitzpatrick 1934, Weaver and Mueller 1942, Weaver and Albertson 1944, Risser et al. 1980, Collins and Wallace 1987, etc.) but very little on the other responses to management regimes. This study is an important step toward addressing those questions.

All of these data should be considered as inconclusive. 1995 and 1996 were both relatively wet years and without dry years to compare, the pattern may be seriously misleading.

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Appendix 1. Percent Flowering by Plot and Year. Summary by treatment shown in Table 4 (above).

Mass of seed production (including caryopsis, excluding stalks) in grams.

		1995			1996		
Treatment	Plot	Number flowering	Total plants	% flower ing	Number flowering	Total plants	% floweri ng
Summer-grazed	7	*			6	18	33.3
Summer-grazed	28	*			16	32	50.0
Summer-grazed	61	*			11	61	18.0
Winter - grazed	36	84	112	75.0	51	52	98.1
Winter - grazed	45	74	256	28.9	78	153	51.0
Winter - grazed	52	23	30	79.3	16	23	69.6
Ungrazed	57	*			37	41	90.2
Ungrazed	58	0	39	0.0	1	38	2.6
Ungrazed	102	*			22	24	91.7
High elevation	BS	*			27	39	62.9
High elevation	BW	*			29	39	74.4
High elevation	FS				24	71	33.8

* Plots not established in 1995.

Appendix 2A. Seed Weight by Plot and Year.

Summary data in Table 5 (above). Mass of seed production (including seed coats, excluding stalks) in grams.

		1995			1996		
Treatment	Plot	Mean	std. dev.	N	Mean	std. dev.	N
Summer-grazed	7	*			0.052	0.094	18
Summer-grazed	28	*			0.111	0.165	30
Summer-grazed	61	*			0.028	0.094	56
Winter - grazed	36	0.447	0.669	107	1.96	2.60	50
Winter -	45	1.674	5.098	225	5.69	17.34	162

grazed							
Winter - grazed	52	1.135	1.599	30	0.316	0.394	23
Ungrazed	57	*			0.480	0.662	44
Ungrazed	58	0.0	0.0	38	0.004	0.026	38
Ungrazed	102	*			4.46	11.27	18
High elevation	BM	*			0.196	0.425	40
High elevation	BW	*			0.122	0.228	39
High elevation	FS	*			0.061	0.160	71

* Plots not established in 1995.

Appendix 2B. Statistical patterns 1996. Results of selected t-tests of seed mass effort.

Management

Plot	SG 28	SG 61	WG 45	WG 52	U 58	U 102	HE BW	HE FS
SG 7	ns	ns						
SG 28		**						
WG 36			ns	**				
WG 45				ns				
U 57					ns	ns		
U 58						*		
HE BM							ns	ns
HE BW								*

Appendix 3. Good Seed by Plot and Year.

Total number of good seeds produced

		1995			1996		
Treatment	*Plot*	*Mean*	*std. dev.*	*N*	*Mean*	*std. dev.*	*N*
Summer-grazed	7	*			0	0	18
Summer-grazed	28	*			0	0	36
Summer-grazed	61	*			0.25	1.47	56
Winter - grazed	45	19.19	76.33	234	75.98	305.40	163
Winter - grazed	52	6.11	14.50	28	0.19	0.64	23
Winter - grazed	58	0.00	0.00	38	0.05	0.32	38
Ungrazed	36	1.23	4.53	99	35.84	62.44	50
Ungrazed	57	*			2.52	8.24	44
Ungrazed	102	*			133.24	457.66	18

High elevation	BM	*			0.12	0.73	40
High elevation	BW	*			0.44	1.31	39
High elevation	FS	*			0.00	0.00	71

* Plots not established in 1995

Appendix 4. Percent Good Seed by Plot and Year.

Total number of good seeds produced

		1995			1996		
Treatment	*Plot*	*Mean*	*Std. dev.*	*N*	*Mean*	*Std. dev.*	*N*
Summer-grazed	7	*			0	0	5
Summer-grazed	28	*			0	0	28
Summer-grazed	61	*			2.592	3.018	7
Winter - grazed	36	1.504	3.957	68	9.933	10.143	49
Winter - grazed	45	6.153	8.722	50	16.491	15.922	76
Winter - grazed	52	2.651	5.024	22	0.498	1.199	16
Ungrazed	57	*			2.941	8.613	40
Ungrazed	58	0	0	39	3.704	-	1
Ungrazed	102	*			6.861	6.187	16
High elevation	BM	*			0.143	0.591	28
High elevation	BW	*			1.938	4.129	18
High elevation	FS	*			0.00	0.00	19

* Plots not established in 1995

Appendix 5. Size of plants in cm^2. Means with a different letter are statistically significantly different at the 5% level.

Treatment	Plot	Mean	std. dev.	N
Summer-grazed	7	1304.4	2618.5	18
Summer-grazed	28	5425.2	12274.8	27
Summer-grazed	61	3692.3	6826.5	61
Winter-	36	1276.6	3032.0	114

grazed				
Winter-grazed	45	978.8	3119.2	267
Winter-grazed	52	9815.2	9127.3	30
Ungrazed	57	1775.5	4156.3	49
Ungrazed	58	4792.5	8331.1	32
Ungrazed	102	6523.3	16987.6	25
High elevation	FS	1930.1	10642.4	71
High elevation	BM	1840.0	3893.0	40
High elevation	BW	1404.5	1644.3	39

Appendix 6A. Percent Good Seed/ Square cm. of Plant, by Plot and Year.

		1995			1996		
Treatment	*Plot*	*Mean*	*Std. dev.*	*N*	*Mean*	*Std. dev.*	*N*
Summer-grazed	7	*			0.00	0.00	18
Summer-grazed	28	*			0.00	0.00	28
Summer-grazed	61	*			<0.001	0.001	56
Winter - grazed	36	0.012	0.073	99	0.245	0.745	44
Winter - grazed	45	0.011	0.042	232	0.470	2.52	150
Winter - grazed	52	0.001	0.002	27	<0.001	0.002	21
Ungrazed	57	*			0.010	0.031	44
Ungrazed	58	0	0	39	0.00	-	33
Ungrazed	102	*			0.018	0.019	18
High elevation	BM	*			<0.001	<0.001	40
High elevation	BW	*			0.001	0.002	39
High elevation	FS	*			0.00	0.00	71

* Plots not established in 1995

Appendix 6B. Statistical patterns 1996. Results of selected t-tests of good seed/sq. cm. of plant. Data in Appendix 6A.

Management

Plot	SG 28	SG 61	WG 45	WG 52	U 58	U 102	HE BW	HE FS
SG 7	ns	ns						
SG 28		ns						
WG 36			ns	ns				
WG 45				ns				
U 57					ns	ns		
U 58						***		
HE BM							*	ns
HE BW								***

Appendix 7.Distribution of Cytotypes. Results of comparing chromosome numbers in Open Space and Mountain Parks plots.

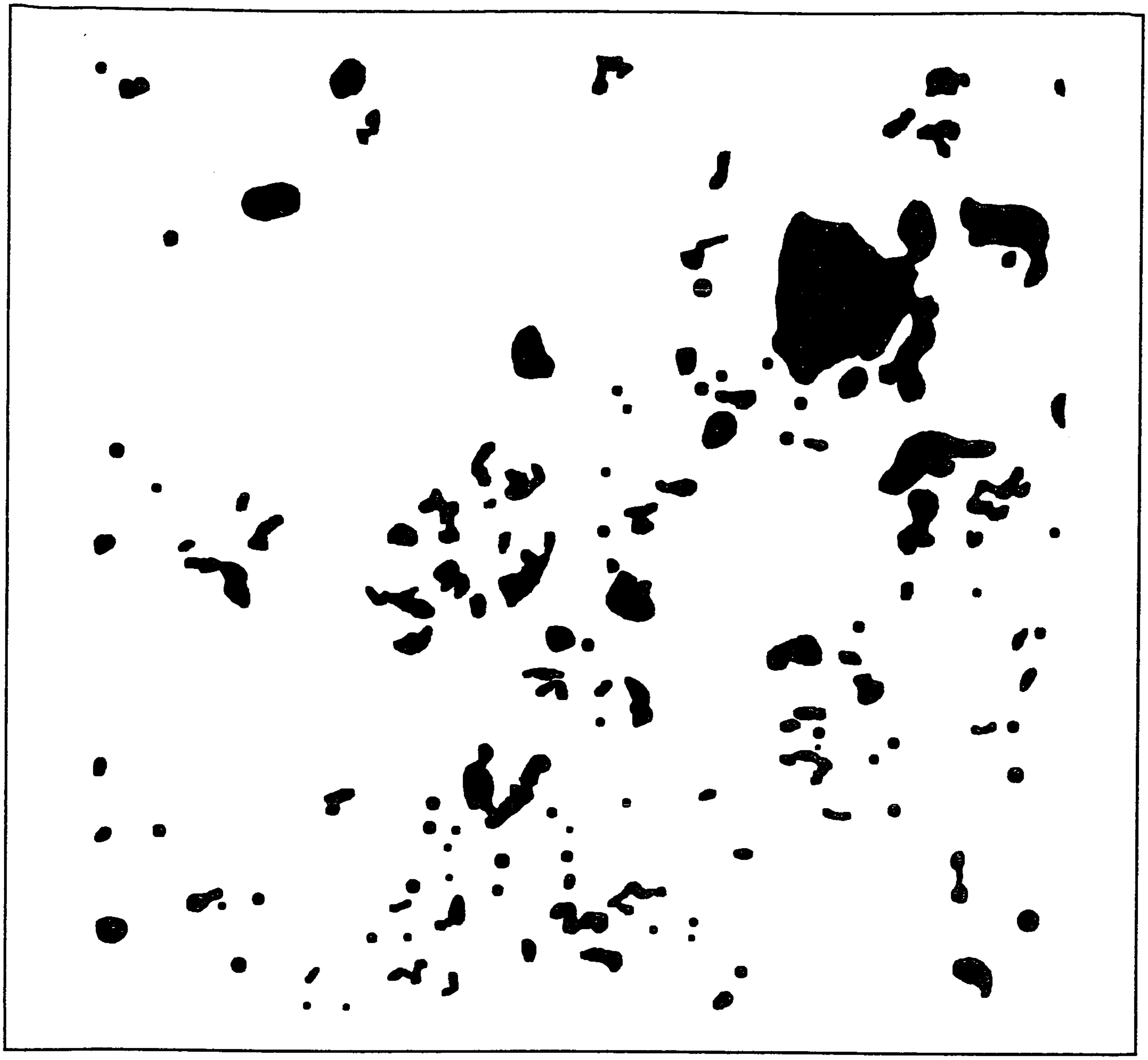
Plot Year Management Plot \	60 N	%	Frequency of Cytotypes 90 N	%	Other N		No. Plants Cytotyped Numbers (% of Total)	Total Plants
52, W	17	0.63	5	0.33	2	0.04	-- (93)	29?
45, W	63	0.73	28	0.25	7	0.08	86 (32)	268
36, W	28	0.49	28	0.49	1	0.02	53 (52)	110
57 U	8	0.47	9	0.53	0	0	17 (38)	45
58 U	12	0.62	7	0.33	1	0.05	(65)	32
102 U	1	0.06	17	0.94	0	0	18 (82)	22
7 S	18	1.00	0	0	0	0	18 (100)	18
28 S	14	0.74	6	0.26	0	0	23 (74)	31
61, S	30	0.76	9	0.18	2	0.06	51 (88)	58
Total	191	63	97	32	13	4	301	

S = summer grazed, W = winter grazed, U = ungrazed

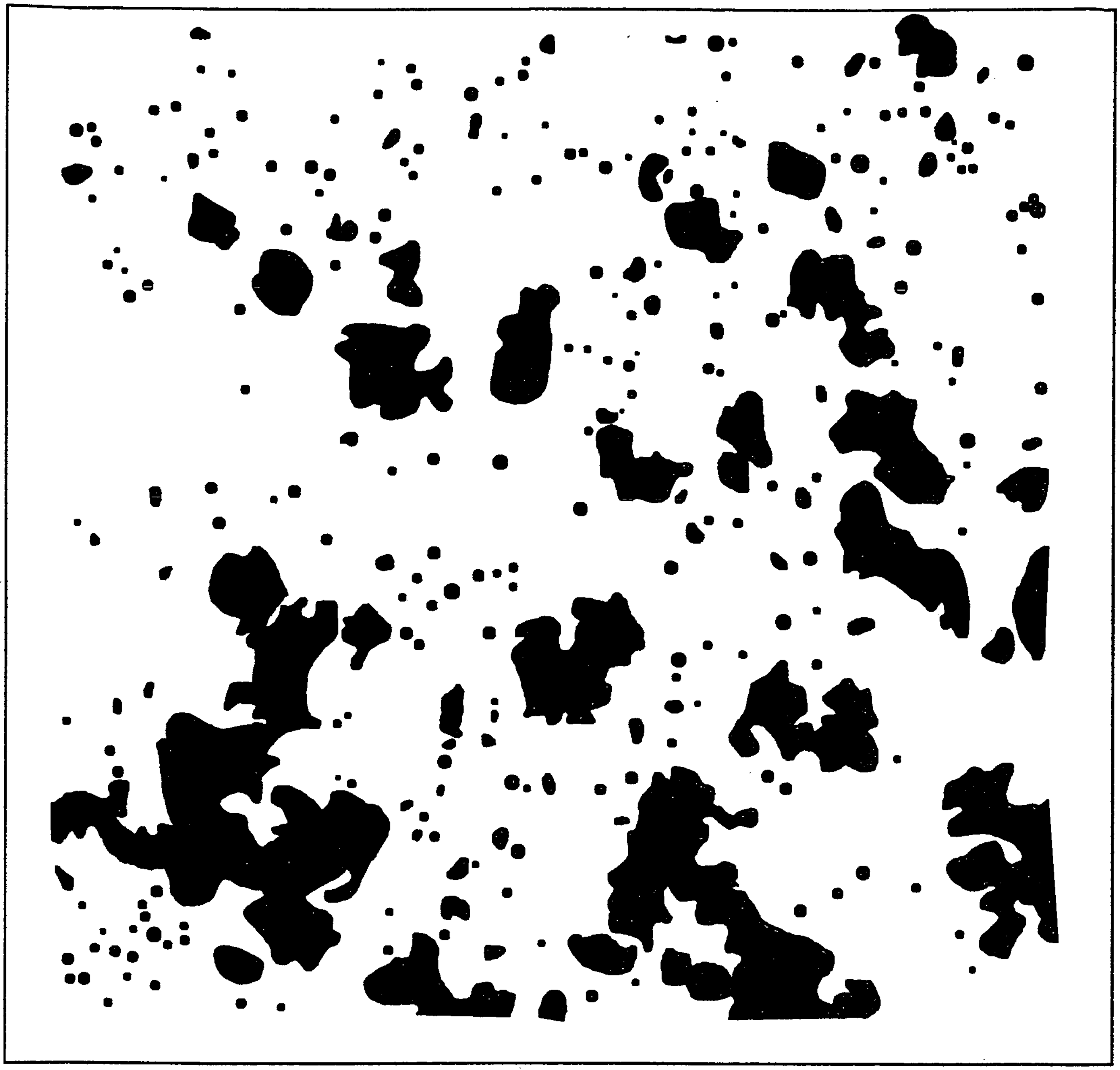
Figures are arranged in numerical order by plot

Plot 36
Plot 45
Plot 52
Plot 57
Plot 58
Plot 61
Plot 102
Plot FS

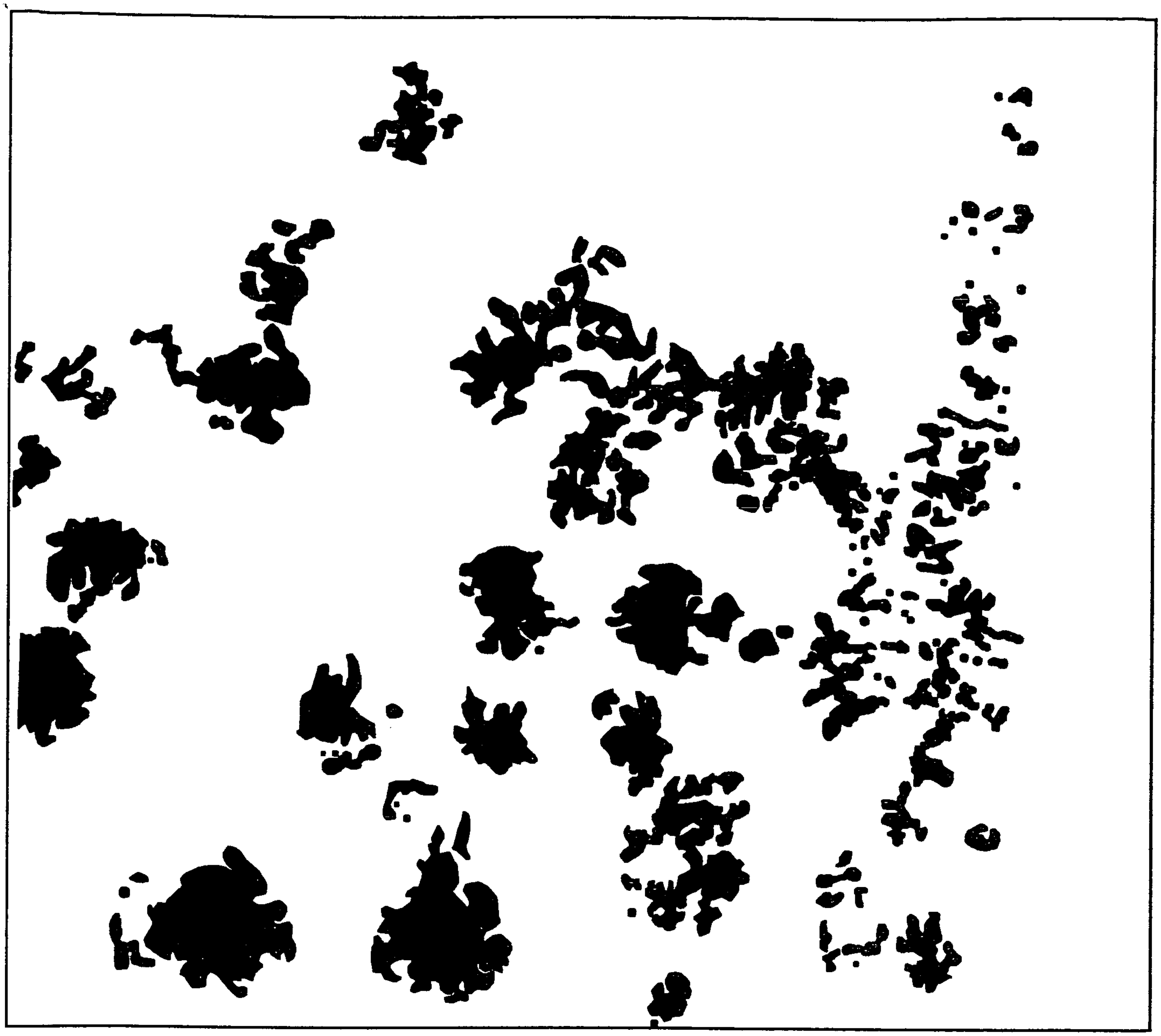
The others are not complete at this time.



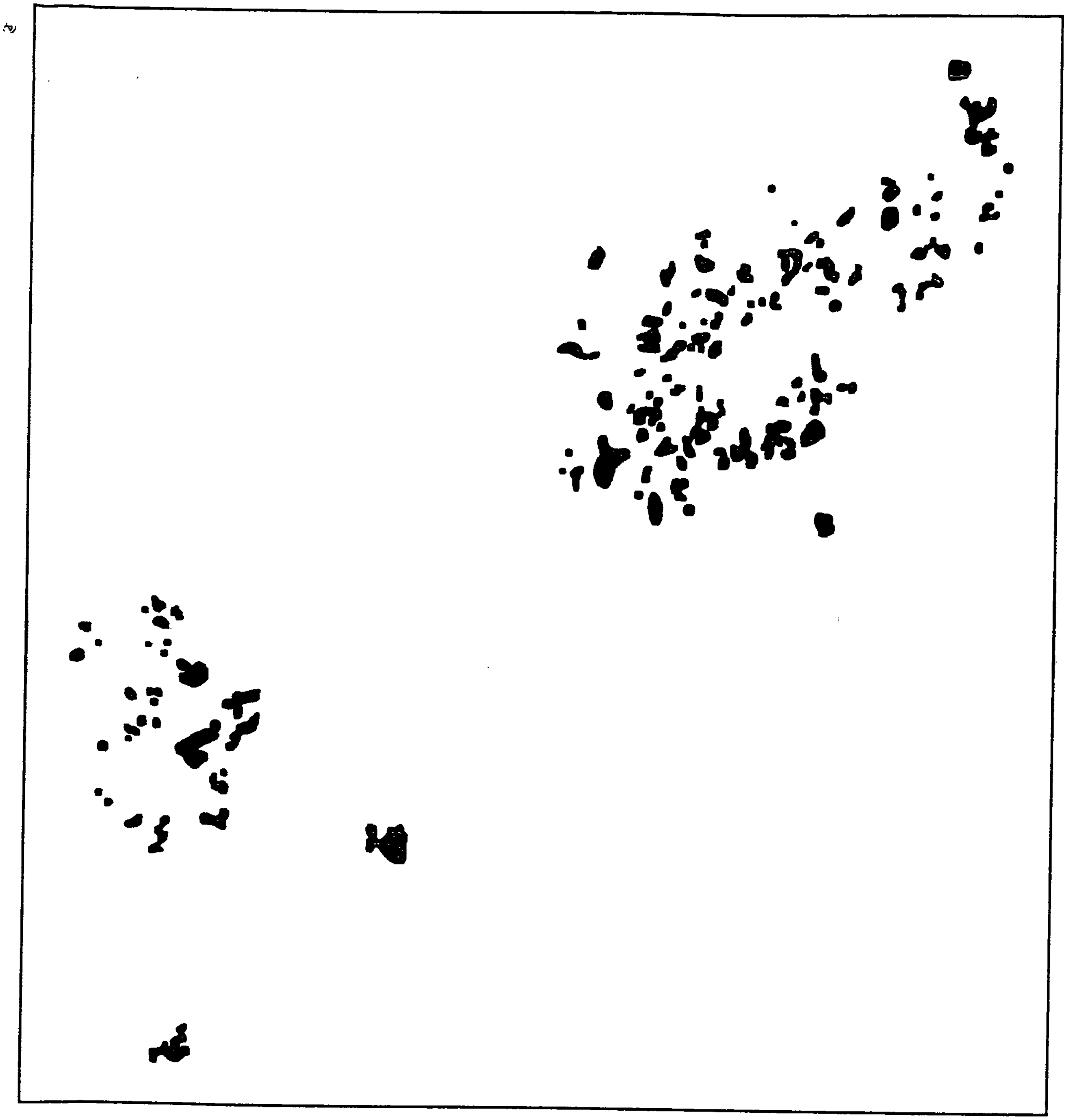
Plot 36. South Boulder Creek



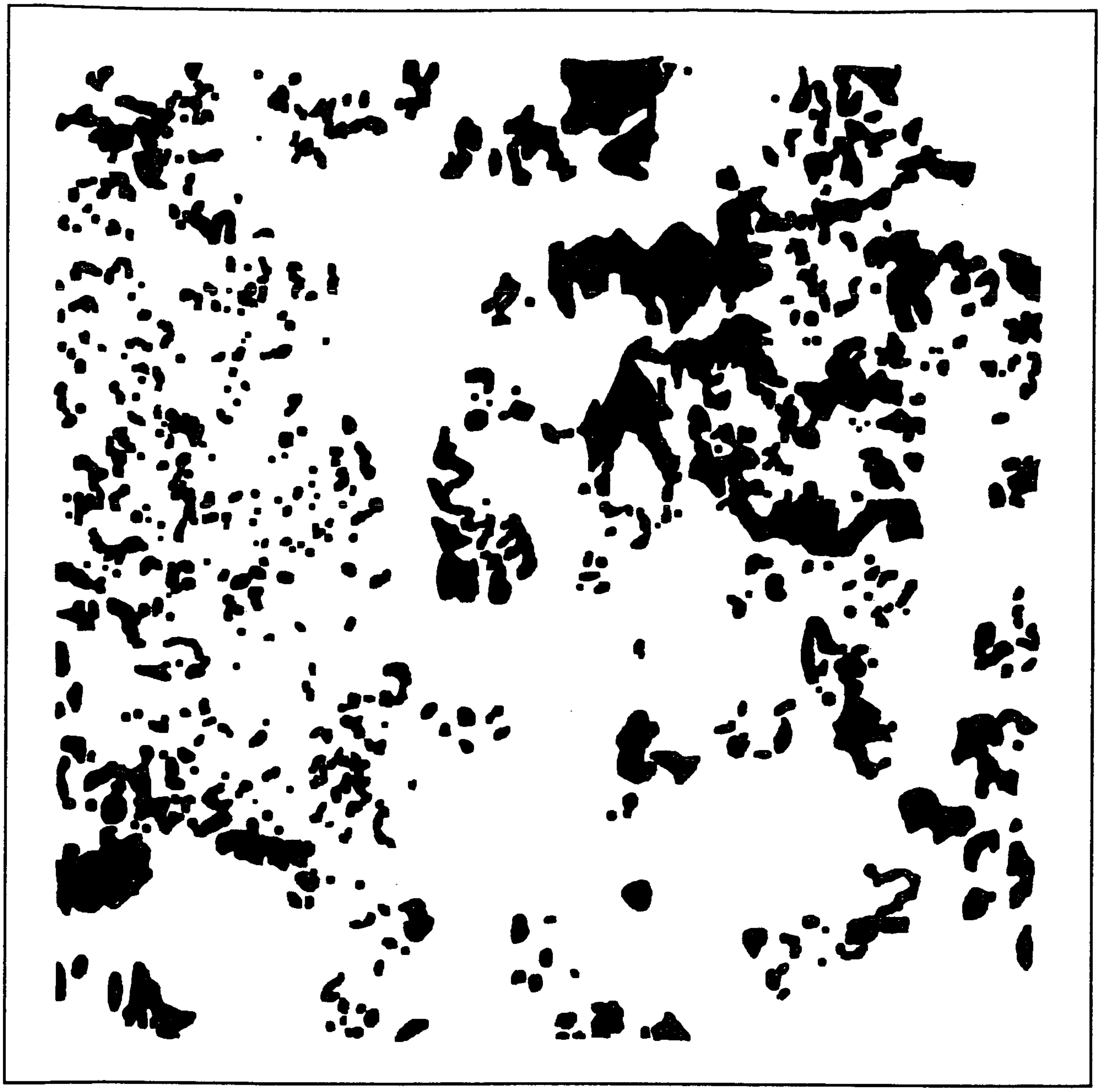
Plot 45. Church Transect.



Plot 52. Davidson Mesa

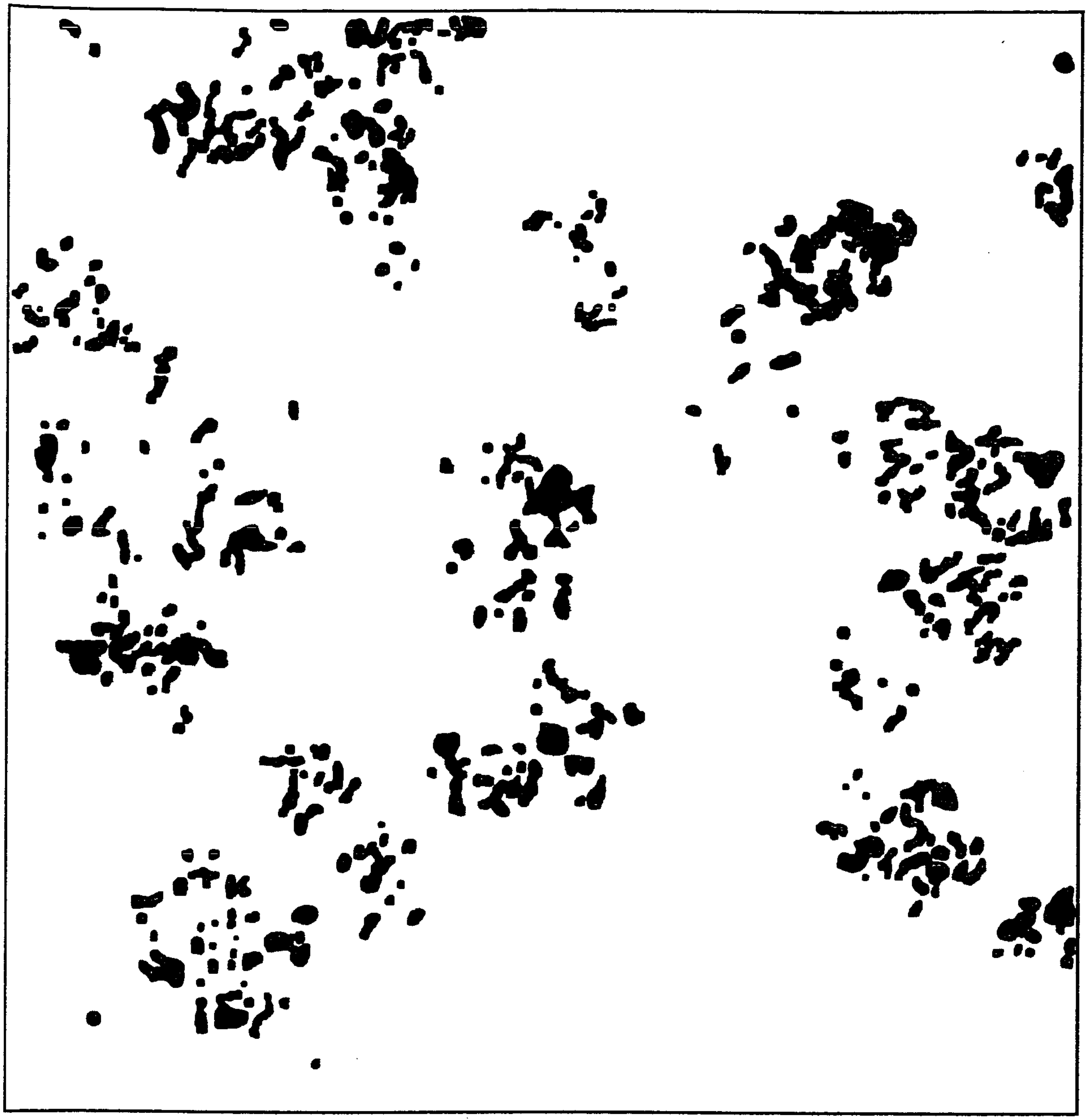


Plot FS: Flagstaff Summit

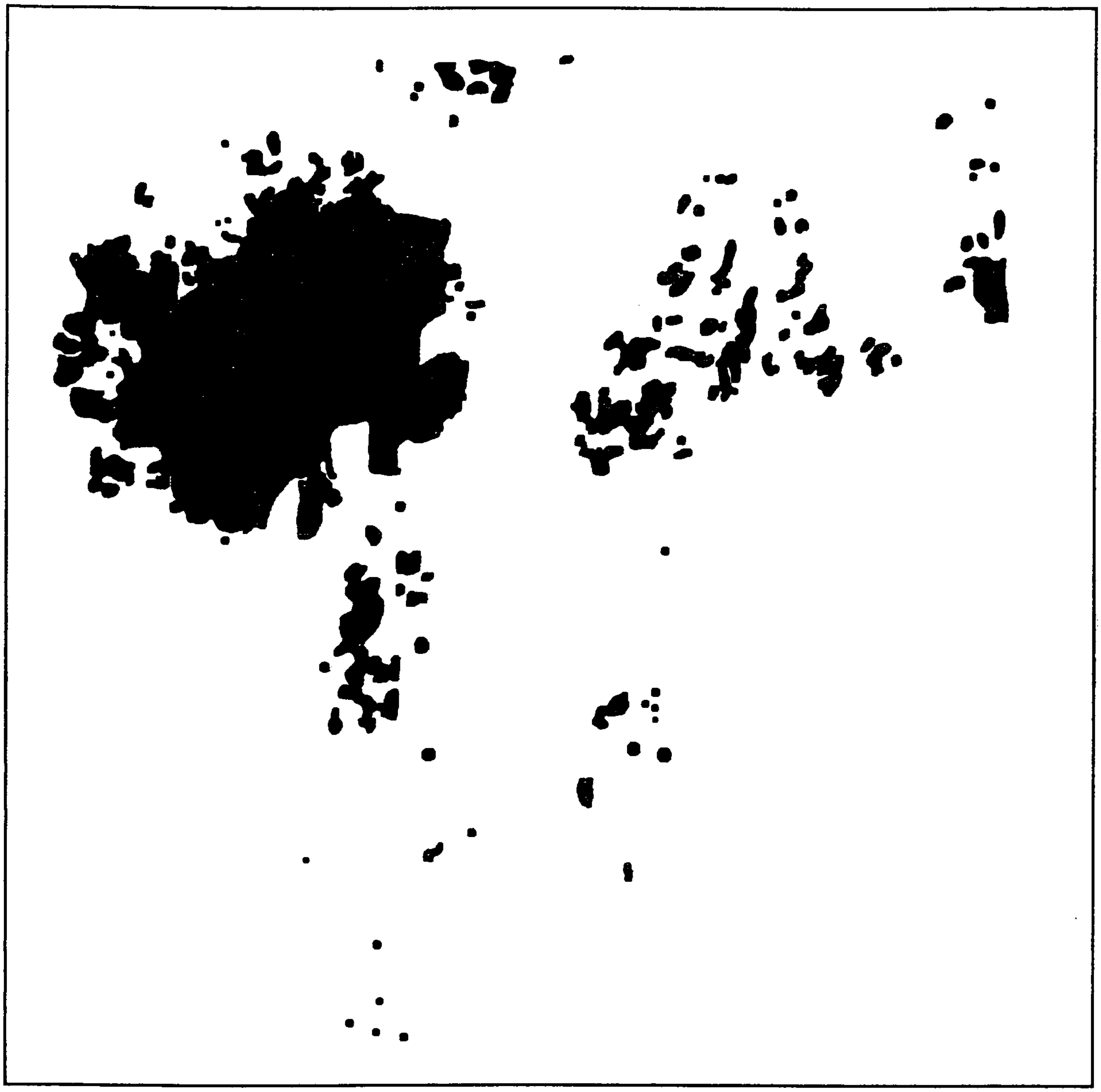


Plot 57. Old OCS grazing exclosure

Plot 58. behind Sans Souci Trailer Park. Ungrazed



Plot 61. Flat Irons Vista



Plot 102. Chataqua Park