Reid Schuller
Natural Areas Association
P.O. Box 1504
Bend, Oregon 97709

VEGETATION RESPONSE TO FALL PRESCRIBED BURNING WITHIN *FESTUCA IDAHOENSIS*-DOMINATED PRAIRIE, MIMA MOUNDS NATURAL AREA PRESERVE, WASHINGTON, 1985-1992

Reid Schuller

Abstract

To determine the vegetation response to fall-prescribed burning at Mima Mounds Natural Area, Washington, I measured the frequency of five native and six non-native prairie species over the 198-1992 time period. I evaluated the effects of two different seasons of burn through systematic random sampling of 100-400 quadrats. These were placed within unburned, summer burned and fall burned experimental areas. Each species response was interpreted by Chi square analysis over the entire period. A conceptual model is developed that characterizes the expected short term (<5 years) response of each species to fall or summer burning. Fall burning was generally observed to be less damaging to native species, especially the dormant native grass *Festuca idahoensis*. Some non-native species such as *Hypochaeris radicata* and *Holcus lanatus* showed a slight (statistically insignificant) decrease under a fall burning regime.

INTRODUCTION

The 440-acre Mima Mounds Natural Area Preserve (NAP) was established in 1977 by the Washington Department of Natural Resources to protect a remnant Puget prairie ecosystem distinguished by "Mima Mound" topography. Management emphasis in NAPs is focused on maintenance or restoration of natural features, native organisms, and the ecological processes which support them.

Over the past century, human alteration of the Puget lowland has been extensive. The introduction of alien (non-native) plant species (Jackson 1982), coupled with the cessation of wildland fire beginning in the early 20th Century (Lang 1961, Giles 1970, Evans *et al.* 1975, and del Moral and Deardorff 1976), have directly affected the ecological conditions present within Mima Mounds NAP today.

Future restoration efforts involving use of prescribed fire within the prairie environment need to be informed by ecological monitoring and research which focus on the potential outcomes of using fire in a setting now coinhabited by alien species. Velvetgrass (*Holcus lanatus*), sweet vernalgrass (*Anthoxanthum odoratum*), Kentucky bluegrass (*Poa pratensis*), and tall oatgrass (*Arrenatherum elatius*), false dandelion (*Hypochaeris radicata*), St. John'swort (*Hypericum perforaturm*) comprise the most aggressive grasses and forbs of this group. *Cytisus scoparius* (Scotch broom) is the most conspicuous alien shrub species at Mima Mounds NAP and in the Puget lowland prairies today.

PURPOSE OF STUDY

This study reports the effects of summer and fall prescribed burning from 1985-1992 on Three roughly 100 x 100m2 areas were subjectively selected based on the (apparent) vegetative similarity to one another. Each of the three areas was randomly assigned a treatment: control, fall burn, and summer burn. Within each 100m2 sampling unit, 4 transect origins were randomly selected along an arbitrary baseline. From each transect origin, a 100m long transect was laid out at right angles to the baseline. Along each transect line, 50 nested frequency (presence/absence) quadrats were systematically placed every 2m along the line. Transect origins were rerandomized each year that sampling occurred. Sampling intensity varied from 400 per experimental unit in 1985, to 200 in 1986-1987, and 100 in 1988-1989, 1992. Three quadrat sizes were employed: 1.0m2, 0.1m2, and 0.01m2. Only live plants rooted within the quadrat were tallied.

In 1985, all plant species encountered in the prairie vegetation were recorded during sampling. Data were recorded for all 63 prairie species encountered during (pre-treatment) 1985 field season. Quantitative data were recorded for 11 species in subsequent years. Nor further data beyond the composition of native and alien grasses and forbs occurring within the prairie environment at Mima Mounds Preserve.

METHODS

1985 were collected for 52 species. This latter group of species all exhibited <20% frequency in all quadrat sizes, and consequently would not be subject to non-parametric testing for trend (see Smith 1982, Hironaka 1985). Moreover, none of the species in the group of 52 were known to be "keystone" species, or alien species capable of having a major influence on prairie plant composition , structure or function over the expected course of the study.

Frequency data for all three quadrat sizes were analyzed by the Chi-square test, a non paramedic measure.

RESULTS AND DISCUSSION

Interpretation of frequency data is difficult because frequency reflects both species density and distribution pattern (Greig-Smith 1983). Plant basal area (Hironaka 1985) and growth form also influence interpretation of frequency data. The following section examines eleven key prairie species trend for the period 1985-89, and 1992. Summary data for all quadrat sizes appear in Tables 1-5.

Table 1. Frequency of key species in the unburned area of Mima Mounds Natural Area Preserve, 1985-89 and 1992. Origin codes: N = native, I = Introduced.

Quadrat		0.01 sq. m						0.1 sq. m						1.0 sq. m					
Year		85	86	87	88	89	92	85	86	87	88	89	92	85	86	87	88	89	92
Grasses																			
AgDi	N	16					8	36	38	28	25	21	22	55	62	53	48	39	45
FeId	N	77		74	50		41	95	90	98	89	93	81	98	98	100	99	100	99
AnOd	I	3					4	8	0	11	1	6	7	14	0	22	5	12	21
HoLa	I	20					3	53	37	34	17	5	12	84	74	66	46	21	44
PoPr	I	11					10	28	36	31	26	22	22	46	51	47	39	43	47
Sedge																			
CaIn	N	34					37	59	54	50	49	48	66	76	78	75	75	67	87
Forbs																			
CaQu	N	20					19	69	64	20	77	97	67	93	92	64	95	98	95
ViAd	N	7					8	14	8	13	11	10	18	24	17	21	26	30	33
ChLe	I	5					7	18	11	23	17	16	17	32	21	33	30	31	40
HyPe	I	16					13	52	46	49	35	38	41	83	77	84	77	70	77
HyRa	I	25					14	64	50	53	51	47	48	91	81	83	83	87	81
Shrub																			
CySc	I	0	0				0	0	0				0	1	0				0

Table 2. Frequency of key species in the summer burn area of Mima Mounds Natural Area Preserve, 1985-89 and 1992. Origin codes: N = native, I = Introduced.

Quadrat		0.01 sq. m				0.1 sq. m				1.0 sq. m			
Year		86	87	88	89	86	87	88	89	86	87	88	89
Grasses													
AgDi	N					24	18	37	42	45	41	68	62
FeId	N		14	13		94	44	50	55	98	86	82	89
AnOd	I					7	4	0	3	11	9	1	7
HoLa	I					44	72	98	52	80	98	99	86
PoPr	I					34	39	23	25	49	53	30	37
Sedge													
CaIn	N					55	47	41	54	82	71	86	80
Forbs													
CaQu	N					67	78	89	73	93	98	99	99
ViAd	N					8	15	14	14	17	26	24	27
ChLe	I					5	2	1	8	8	7	6	16
HyPe	I					52	44	34	33	75	81	65	69
HyRa	I					41	75	97	95	71	99	98	100
Shrub													
CySc	I					0				0			

Table 3. Frequency of key species in the fall burn area of Mima Mounds Natural Area Preserve, 1985-89 and 1992. Origin codes: N = native, I = Introduced. This area was burned after sampling in 1985 and never burned again.

Quadrat		0.01 sq. m						0.1 sq. m						1.0 sq. m					
Year		85	86	87	88	89	92	85	86	87	88	89	92	85	86	87	88	89	92
Grasses																			
AgDi	N	15					14	30	47	36	48	60	33	48	68	63	75	83	58
FeId	N	91		48	50		44	100	87	94	91	93	86	100	99	100	100	99	99
AnOd	I	0					1	0	0	1	0	0	1	1	0	1	0	0	2
HoLa	I	22					4	56	59	34	19	8	8	84	81	65	66	21	28
PoPr	I	5					2	15	18	11	16	14	4	30	26	27	23	21	11
Sedge																			
CaIn	N	35					36	57	40	40	45	53	75	74	62	63	71	76	91
Forbs																			
CaQu	N	15					36	57	80	40	45	53	75	74	62	63	71	76	91
ViAd	N	3					4	9	13	17	11	19	10	18	21	32	22	29	15
ChLe	I	0					2	1	0	2	1	3	4	1	0	4	4	5	6
HyPe	I	21					2	61	63	55	42	53	14	86	81	84	76	84	35
HyRa	I	41					21	81	70	89	99	92	70	96	90	100	100	100	92
Shrub																			
CySc	I	1	0				8	3	3				24	6	4				40

Table 4. Frequency of key species in the fall burn area of Mima Mounds Natural Area Preserve, 1985-89 and 1992. Origin codes: N = native, I = Introduced. This area was burned after sampling in 1985 and burned again in 1987.

Quadrat		0.01 sq. m						0.1 sq. m						1.0 sq. m					
Year		85	86	87	88	89	92	85	86	87	88	89	92	85	86	87	88	89	92
Grasses																			
AgDi	N	15					23	30	47	47	50	64	42	48	68	71	73	86	72
FeId	N	91		53	38		40	100	87	92	82	81	78	100	99	100	99	99	99
AnOd	I	0					1	0	0	0	0	1	3	1	0	0	0	1	4
HoLa	I	22					2	56	59	37	47	29	6	84	81	71	92	51	35
PoPr	I	5					3	15	18	14	25	20	6	30	26	25	32	30	9
Sedge																			
CaIn	N	35					34	57	40	37	48	51	60	74	62	60	69	77	89
Forbs																			
CaQu	N	15					22	57	80	50	87	75	65	89	96	97	99	98	92
ViAd	N	3					5	9	13	10	15	19	10	18	21	16	24	30	15
ChLe	I	0					1	1	0	0	0	1	2	1	0	0	0	1	4
HyPe	I	21					11	61	63	56	43	45	24	86	81	89	79	81	49
HyRa	I	41					42	81	70	95	91	94	87	96	90	100	100	100	100
Shrub																			
CySc	I	1	0				7	3	3				18	6	4				42

Table 5. Frequency of key species in the fall burn area of Mima Mounds Natural Area Preserve, 1985-89 and 1992. Origin codes: N = native, I = Introduced. This area was burned after sampling in 1985 and burned again in 1988.

Quadrat		0.01 sq. m						0.1 sq. m						1.0 sq. m					
Year		85	86	87	88	89	92	85	86	87	88	89	92	85	86	87	88	89	92
Grasses																			
AgDi	N	15					21	30	47	49	54	55	44	48	68	68	73	75	69
FeId	N	91		47	54		38	100	87	92	96	92	86	100	99	99	100	100	100
AnOd	I	0					0	0	0	1	0	0	0	1	0	1	0	0	1
HoLa	I	22					5	56	59	39	27	8	17	84	81	66	59	29	51
PoPr	I	5					9	15	18	8	15	17	18	30	26	20	28	27	23
Sedge																			
CaIn	N	35					26	57	40	41	35	45	53	74	62	64	60	64	79
Forbs																			
CaQu	N	15					48	57	80	51	91	92	88	89	96	96	99	99	99
ViAd	N	3					5	9	13	9	11	16	11	18	21	14	20	21	26
ChLe	I	0					0	1	0	0	0	0	1	1	0	1	1	1	3
HyPe	I	21					11	61	63	46	49	60	40	86	81	73	85	85	73
HyRa	I	41					32	81	70	93	90	87	83	96	90	100	99	100	100
Shrub																			
CySc	I	1	0				2	3	3				7	6	4				18

Festuca idahoensis **(Idaho fescue) - NATIVE, PERENNIAL, GRASS**

Table 1 shows a substantial decline in the control (unburned) prairie plot, from 74 to 50% frequency ($p<0.0001$) between 1987 and 1988. This decline continued in the smallest quadrat size into 1992 (41%). Nine of the ten other species recorded also experience declining frequency during this period. Precipitation data taken from Olympia Airport from October 1987 through September 1988 indicate a "crop season" annual total of 19.51 inches. This is 10-20% below the average for this period when compared with 1984-1993 data. It is unlikely, however, that this drop in annual precipation could, by itself, account for the declining frequency of Idaho fescue.

The "summer" burn in 1986 occurred on July 7th. Data collected prior to the burn indicate a drop in the mid-sized quadrat from 94% in 1986 to 44% in 1987 ($p<0.0001$). A corresponding drop occurred during this period in the largest quadrat size (98-86%, $p<0.0001$) (Table 2).

The fall burn occurred in September, 1985. Data in Table 3 (also see Figure 1) shows a 2-year decline in the small-quadrat size frequency from 91% to 46% ($p<0.0001$), two years after the burn. This level was maintained up to 1992, when 44% was recorded ($p<0.0001$). The two larger sized quadrats show no significant decline during these periods.

Idaho fescue response to a two-year fire return interval is shown in Table 4; response to a three-year fire return interval is shown in Table 5. Data from the 2-year return shows a slight decline in frequency after both burns in the small- and mid-size quadrats. No decline was observed in the larger quadrat.

The seven year record for Idaho fescue indicates a change from 91% to 46% frequency (p<0.0001) in the small quadrat, and 100% to 78% in the midsized quadrat, with no change observed in the large quadrat. A similar pattern exists for fescue under the three-year fire return interval: a decline from 91% to 38% (p<0.0001) frequency in the small quadrat; a decline from 100% to 86% (p<0.0001) in the mid-size quadrat, and no change in the large quadrat.

The general trend in frequency for Idaho fescue over the course of the project was one of decline. However, because this trend also occurred in the unburned (control) prairie sample, this trend can not be primarily linked to the fall burn treatments, whether they be a single burn or two burn with either a 2- or 3-year fire return interval.

***Agrostis diegoensis* (thin bentgrass) - NATIVE, PERENNIAL, GRASS**

Table 1 shows a general decline in frequency over the seven year course of the project in the control sampling area. The mid-size quadrat indicates a drop from 36% in 1985 to 22% in 1992 (p=0.078). The large quadrat also shows a slight, although insignificant, decline during this period.

Data from Table 2 suggests that *A. diegoensis* responded favorably to the July, 1986 burn. After a small decline in 1987, the year after the burn, frequency in both the mid- and large-quadrats increased in 1988 and 1989 (24%-42%, p=0.0068; and 45%-62%, p=0.0159) respectively.

Thin bentgrass appears to be neutral to fall burning (Table 3). Over the course of the study, frequency varied greatly, but apparently not in response to the prescribed fire regime employed in the sampling plots. Although declines in bentgrass frequency occurred during the 1985-1992 period, only increases in frequency occurred the year after a burn in each of the three, fall burn regimes: one-time burn, two-year return interval, and three-year return interval (Tables 3, 4 and 5; Figure 2).

***Carex inops* (woolly sedge) - NATIVE, PERENNIAL, GRASS-LIKE**

No significant changes in frequency were observed over the course of the project in the control (unburned) sampling area (Table 1). Similarly, no significant trends were observed in the summer, of fall burns during this period. However, slight increases in frequency in the mid- and large-size quadrats are evident in the one-time fall burn, and the two-year return interval fall burn.

Woolly sedge trend over the course of the project is neutral to mildly positive to all burning regimes to which it was subjected (Figure 3).

***Camassia quamash* (camas) - NATIVE, PERENNIAL, FORB**

The small-, mid-, and large-size quadrats show that no significant changes in frequency of camas occurred in the control (unburned) plots during the 1985-1992 time period. One interesting anomaly is the large drop in frequency in 1987 recorded in the mid- and large-quadrats. Frequency returned to pre-1987 levels in both quadrat sizes in 1988 (Table 1). No significant trends were observed in the response of camas to summer burning (Table 2; also see Figure 4). Table 3 indicates an increase in frequency between 1985 and 1986 in the mid- (58-80%, p<0.00001) and large-size (89-96%, p=0.0041) quadrats, indicating a favorable response to one-time fall burning. The response is further supported by examining Table 4, where a second increase following burning occurs in the mid-sized quadrat between 1987 and 1988 (50%-87%, p<0.0001). It is doubtful whether thi pattern can be solely attributed to the 2-year fire return interval, however.

The 3-year fire return interval (1985-1988) produced no significant increases in camas after the second burn. The overall pattern during the 1985-1992 period was one of significant increase in camas frequency in all fall burn plots compared to the control plots during the period. Examination of the mid-size quadrat (Tables 3, 4, and 5) data is most revealing here. In all three fall burn data sets, the initial increase in camas frequency occurred after the first burn in 1985. It is likely that the removal of surface fuel "released" the camas that was persisting in bulb form below ground prior to the fall burn.

Viola adunca (prairie violet) - NATIVE, PERENNIAL, FORB

Prairie violet frequency levels did not change appreciably in the control (24-33%,
After the summer 1986 burn, velvetgrass frequency increased substantially for the following two years, with a subsequent decline in 1989 (Table 2). The post-fire surge in frequency values most likely can be attributed to the removal of surface vegetation and exposure of mineral soil, although this was not tested experimentally. Numerous seedlings were observed after the summer 1986 burn, especially in 1987. Whether the 1989 decline in frequency

p=0.0658) sampling area during the 1985-1992 period (Table 1).

Mid- and large-size quadrat data from the summer burn (Table 2) suggest a moderate increase in prairie violet frequency (8%-15%, p=0.0282; and 17%-26%, p=0.0285 respectively) during the 1986-1987 period. No significant trends were detected in any of the three fall burn fire regimes. However, Table 4 indicates a very slight increase in mid- and large-size quadrats in prairie violet frequency the year after a prescribed fire.

Taken as a whole, prairie violet responded neutrally to all fire regimes to which it was subjected. Although slight and temporary increases in frequency are evident for short periods of time following each burn (Figure 5).

Holcus lanatus (velvetgrass) - INTRODUCED, PERENNIAL, GRASS

Velvetgrass experienced a decline in frequency in the control area over the 1985-1992 time period. All three quadrat sizes evidenced this decline (20%-3%, 53%-12%, 84%44%; all p<0.00001). The mid- and large-size quadrats indicate that 1989 was the low year in per cent frequency, and a slight rebound occurred by 1992 (Table 1).

represents increased interference from surrounding vegetation, remains a subject for speculation and future monitoring.

The one-time fall burn in 1985 data reveal a steady decline in velvetgrass frequency percentages beginning two years after the burn (Table 3). All three quadrat sizes substantiate this trend (22%-4%, 56%-8%, 84%-28%; all p<0.00001). The two-year fire return interval (1985, 1987 burns) data show a slight increase in frequency the year after each burn, followed by a substantial decline in 1992 in both the mid- and large-size quadrats (Table 4). The three year fire return interval (1985, 1988 burns) indicates substantial decline in frequency in 1988, the year following the second burn: from 27%-8% (p=0.0001), and 59%-29% (p<0.00001) in the mid- and large-size quadrats, respectively (Table 5).

Overall the trend in response to burning is mixed. The July burn (summer) appears to have a stimulating effect on velvetgrass. However, it is plausible that the high precipitation in September (3.38 in.) and October (4.12 in.) following the burn contributed to higher levels of seed production and germination of velvetgrass in relation to other species occupying the site. The percentage frequency decline in the control area limits interpretation of a similar trend in the fall burn plots, leaving open the question regarding the future trend of velvetgrass in a fall burn fire regime.

***Poa pratensis* (Kentucky bluegrass) - INTRODUCED, PERENNIAL, GRASS**

No apparent trend in sweet vernalgrass frequency is evident in the control (unburned) sampling area for the 1985-1992 period (large-size quadrat 14%-21%, p=0.0961)(Table 1). Similarly, no clear trend is established in the summer 1986 burn data set (Table 2). Frequency percentages were too low in all three fall burn fire regime data sets to allow for interpretation.

Based on limited data, the apparent trend of *Anthoxanthum* in response to any fall burning regime is neutral.

***Hypochaeris radicata* (false dandelion) -**

No significant trends were observed in Kentucky bluegrass frequency within the control (unburned) sampling area during the course of the study. The summer burn area data shows a frequency decline between 1987 and 1988 in both the mid- (39%-23%, p=0.0057) and large-size (53%-30%, p=0.0002) quadrats (Table 2). This corresponds to similar declines during this period for many of the species for which data was collected.

The one-time fall burn data set shows no pattern in trend until 1992, when frequency declines in the mid- and large-size quadrats (Table 3). However, it is highly unlikely this decline can be attributed to the one-time burn in 1985. A similar pattern and interpretation can be made for the two-year fire return interval data set for the mid- and large-size quadrats (Table 4). No trend is evident in the 3-year fire return interval data set.

***Anthoxanthum odoratum* (sweet vernalgrass) - INTRODUCED, PERENNIAL, GRASS**

INTRODUCED, PERENNIAL, FORB

Data from the mid-size quadrat indicates a significant decline in false dandelion frequency within the control area during the 1985-1992 time period (64%-48%, p=0.0029) (Table 1). In contrast, 1986 summer burn data show a marked increase in frequency one, two, and three years after the burn. For the years 1986-1986, the mid-size quadrat data show 41%, 75%, 97%, and 95% respectively This same pattern is further substantiated by the large-size quadrat data (Table 2).

The one-time fall burn data set (Table 3) shows a 50% reduction (41%-21%, p<0.0001) in percent frequency in the small-size quadrat between 1985 and 1992 (with no measurements in this size quadrat being taken in the intervening time period) (Table 3). This reduction in frequency is not evident in the small size quadrat data sets for the 2-year and 3-year fire return intervals (Tables 4 and 5). No other trends are evident in the mid- and large-size quadrat data sets for the fall burns.

Although abundant throughout the study area, taken as a whole, the trend of *Hypochaeris* appears to be relatively stable throughout the course of the study for all 3 fall burn fire treatments. However, increases in frequecy in response to July burning are evident in all three quadrats sizes.

***Hypericum perforatum* (St. Johnswort) - INTRODUCED, PERENNIAL, FORB**

The control (unburned) data set indicates no apparent trend in St. Johnswort percentage frequency for the mid- and large-size quadrats. The small-size quadrat data exist only for the first (1985) and last (1992) years of the project, and suggest the possibility of a declining trend in St. Johnswort frequency (25%-14%, p=0190) (Table 1).

Data for one to three years after the summer 1986 burn show moderate declines in *Hypericum* percentage frequency in the mid-size quadrats. This trend is not evident in the large-size quadrats for the same time period (Table 2).

Fall burn data show mixed results. The one-time fall burn (Table 3) and the two-year fire return interval (Table 4) show a moderate to sharp decline in St. Johnswort frequency between 1989 and 1992. Whether these declines may be attributed primarily to the prescribed burns undertaken in 1985 and 1987 is uncertain. The three-year fire return interval data indicate no decline in trend from 1985-1992.

***Chrysanthemum leucanthemum* (oxeye daisy) - INTRODUCED, PERENNIAL, FORB**

No apparent trend in oxeye daisy frequency is evident in the control (unburned) sampling area for the 1985-1992 period (Table 1). The low percentage frequency values for the summer burn and all three fall burn data sets preclude interpretation..

Tabular Summary of Individual Species Response to Burning Regimes

The two following tables condense the results and discussion section into a simple fire response "model", which could be used as a guide in prescribed fire planning at Mima Mounds Preserve (for short-term e.g., < 5year responses). They are not intended to replace more detailed investigation into population or other ecological studies, which are likely to alert the reader to other important aspects of conservation management not addressed in this study. Application of these models should be as a preliminary guide which will require modifications based on future monitoring and/or research.

Table 6. Seven year response to fall and summer burning. * Observations based on limited data.

Species	Fall Burn	Summer Burn
Native Species		
Festuca idahoensis	Neutral to Mild Decreaser Depending on fire behavior	Decreaser
Agrostis diegoensis	Neutral	Mild Increaser
Carex inops	Neutral	Neutral
Camassia quamash	Increaser	Neutral
Viola adunca	Neutral	Mild Increaser
Introduced Species		
Holcus lanatus	Mild Decreaser -variable	Undetermined
Poa pratensis	Neutral	Neutral to Mild Increaser
Anthoxanthum Odoratum	Neutral *	Neutral*
Hypochaeris Radicata	Neutral to Mild Decreaser	Increaser
Hypericum Perforatum	Neutral	Neutral
Chrysantheum Leucanthemum	Undetermined*	Undetermined*

REFERENCES CITED

del Moral, R., and D.C. Deardorff. 1975. Vegetation of the Mima Mounds, Washington state. Ecology 57(3):520-530.

Evans, S., M. Gilbert, C. Johnson, and J. Schuett. 1975. The *Pseudotsuga menziesii* invasion on Mima Prairie: a study of prairie-forest dynamics. pp. 63-108 in: S. Herman and A. Wiedemann (eds.) Contributions to the natural history of the southern Puget Sound region, Washington. The Evergreen State College, Olympia. 249p.

Giles, L.J. 1970. The ecology of the mounds of Mima Prairie with special reference to Douglas-fir invasion. M.S. thesis, University of Washington, Seattle. 98p.

Greig-Smith, P. 1983. Quantitative plant ecology. University of California Press, Berkeley. 359p.

Hironaka, M. 1985. Frequency approaches to monitor rangeland vegetation: Symposium on use of frequency and density for rangeland monitoring. In: Krueger, W.C. (chairman). Proceedings 38th annual meeting, Society for Range Management; 1985 February; Salt Lake City, UT. Denver, Colorado: Society for Range Managment. p. 84-86.

Jackson, L.E. 1982. Comparison of phenological patterns in prairie and subalpine meadow communities. Northwest Science 56(4):316-328.

Lang, F.A. 1961. A study of vegetation change on the gravelly prairies of Pierce and Thurston counties, Washington. M.S. thesis, University of Washington, Seattle. 109p.

Smith, S.D. 1982. Evaluation of the frequency plot method as an improved technique for measuring successional trend. M.S. Thesis. University of Idaho, Moscow. 95p.