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GRASSLAND BIOME STUDIES AT THE BRIDGER SITE, 1971

Don D. Collins and Theodore W. Weaver III

Department of Botany and Microbiology

Montana State University

Bozeman, Montana

GRASSLAND BIOME

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ABSTRACT

The Bridger Site and 1971 activities performed there are briefly described. Production data are presented and compared with 1970 figures in the light of environmental conditions during each year. Gopher (*Thomomys*) numbers were similar to those recorded for 1970, but vole (*Microtus*) populations declined sharply.

INTRODUCTION

The objectives of the studies were to measure aboveground vegetative production and general phenology in a mountain meadow and to relate them to environmental parameters. Mammal populations were compared on the ungrazed, sheep-grazed, and cattle-grazed sites. The study area lies between 6000 and 8000 ft on the Bangtail Mesa, 22 km northwest of Bozeman, Montana (46°47'N latitude, 110°44'W longitude). Forests of *Pinus contorta* and *Abies lasiocarpa* cover 75% of the area; the remainder is covered by *Festuca idahoensis* meadows. The study site proper is 7800 ft and consists of a 35-acre area (fenced since 1930) and adjoining lands which are continuously grazed.

STUDIES

Methods

Vegetation. Standing crops in two plots within the ungrazed area were measured fortnightly. These plots are called Control 1 and Control 2 because they are compared in another study with areas on which snow pack is artificially increased. In each plot, ten blocks of ten .5-m^2 plots were located. A randomly chosen plot (1 × 0.5 m) from each of these was studied at each sampling period. The plot was clipped, and the clippings were separated into 15 classes, including six grass species, eight forb species, and standing dead; litter was gathered and bagged as well.

The material gathered in the field was dried to constant weight at 60°C and weighed. None of it was ashed or analyzed for mineral content. Means and standard deviations for the weight, species, total forbs, total grasses, and for the total standing crop were calculated for each plot ($n = 10$) and for the area as a whole ($n = 20$).

Litter decomposition. Three sets of litter bags were placed in the field on 2 July 1971; decomposition rates will be determined by following weight loss with time. No results are given in this report. Each nylon net bag was filled with 10.4 g of *Festuca idahoensis*. One set of bags was buried (5 to 7 cm), one set lies on the ground surface, and one set is held 1 cm above the surface to simulate loose litter.

Phenology. Phenology was recorded weekly for four major grasses and sixteen forbs in five 1 × 10 m plots. Predominant stages as well as relative numbers of plants in each stage were recorded.

Small mammals. Microtus montanus was trapped in four grazed meadows: early melting sheep-or cattle-grazed and late melting sheep-or cattle-grazed. The early melting sheep-grazed site was that studied by Hoffmann, Jones, and Genoways (1971). There were 144 baited traps placed in each meadow in a grid of 15 × 15 m units for 6 days. Trap positions were shifted from grid corners to grid centers after the first 3 days. Four trapping periods were used (9 June, 6 July, 2 August, and 31 August).

An index of gopher (*Thomomys talpoides*) activity was made by leveling the mounds in these areas and counting the new mounds after 48 hr. Five grids (including both the Hoffmann grids) were studied 7 to 12 August.

Environmental data. A U.S. Weather Bureau Station (Bangtail Ridge) less than a mile from the study site provides temperature and precipitation data for most of the year (Table 1; Meuggler, 1971).

On the site we have measured temperature (air and soil), humidity, soil water, average wind flow, precipitation, evaporation, and solar radiation. Air temperatures and humidity were measured in a standard weather bureau shelter with a Belfort hygrothermograph and a Taylor Six's max-min thermometer. Soil temperatures were recorded continuously at 10 and 50 cm.

Table 1. Climatological data for Bangtail Ridge, 1969 to 1971, U.S. Weather Bureau.

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Precipitation (inches)												
1969											1.57E	2.77E
1970	5.44	2.42	4.07	5.04	3.80	2.97	2.22	0.58	1.44E	3.58E	4.26E	2.94
1971	4.29	4.27	--	4.77	3.32	2.82	0.06	1.7	2.28			
Temperature (°F)												
Average max												
1969										36.1	35.7	27.6
1970	23.9	33.0	28.2	--	44.6	58.2	70.8	72.3	--	41.4	--	21.0
1971	21.7	25.9	26.9	--	40.5	56.7	65.8	75.8	49.7			
Average min[a/]												
1969										20.6	21.2	15.8
1970	12.4	17.8	11.2	--	31.9	41.1	48.0	49.0	--	25.2	--	10.5
1971	12.2	13.4E	12.8	--	26.1	39.3	43.7	53.1	33.8			
Absolute max												
1969										61	51	46
1970	36	49	40	--	60	79	79	80	68	64	--	34
1971	41	38	42	--	55	74	78	83	68			
Absolute min												
1969										3	3	0
1970	19	0	-4	--	19	24	35	38	14	10	--	-11
1971	-26	--	-5	5	14	26	31	35	20			

[a/] 1970 frost-free season at Bangtail Ridge: above 32°F = 70 days (30 June to 8 September) and above 24°F = 102 days (14 May to 11 September).

Soil water values were measured at 10, 25, and 75 cm with plaster blocks and a resistance meter. Total wind flow (2 m) was recorded at weekly intervals with a Belfort three-cup anemometer. Total radiation was measured with a Belfort pyreheliograph. Precipitation was measured with standard weather bureau rain gages. Evaporation was measured as water loss from a no. 1 galvanized washtub.

Sampling dates and numbers. Twenty 1 × 0.5 m plots were chosen in the ungrazed area and clipped as described above on Tuesdays of alternate weeks (15 June, 30 June, 13 July, 27 July, 9 August, and 24 August). Meteorological and phenological data were recorded on the day following vegetation sampling. Dates of small mammal measurements are given under the small mammal section.

Related Data

Status of samples. The vegetation data has been gathered and summarized. Much of it is presented in Tables 2, 3, and 4. Meteorological data appears in Tables 5 and 6. Small mammal data from 1971 is compared with that from 1970 in the preliminary synthesis section. Comparisons of 1969, 1970, and 1971 data are just being made.

Related studies. A general site description appears in Collins (1970). Soils of the area have been characterized by Buchanan (1972). 1970 vegetation data are presented and discussed by Collins (1971). Bridger data are compared with that of other Grassland Biome sites in French (1971), Grant (1971*a*,*b*), and Hoffmann et al. (1971).

Abiotic data. Meteorologic equipment and sampling dates are given in the environmental data section. Results are summarized in Tables 5 and 6. Soils of the area are discussed in Buchanan (1972).

Table 2. Bimonthly vegetational standing crop, Bangtail Mesa Site (1971), control plots (both replicates) in g dry wt/m^2.

Species	Date of Sample					
	15 June	30 June	13 July	27 July	9 August	24 August
			Grasses			
Agropyron subsecundum						
mean	9.44	20.25	23.31	27.31	37.97	40.52
standard deviation	5.26	9.56	18.40	23.59	51.25	40.37
Carex sp.						
mean	0.86	3.26	3.51	4.46	6.67	4.07
standard deviation	2.43	5.62	2.97	6.63	7.44	8.03
Danthonia intermedia						
mean	0.12	2.39	5.68	8.57	5.16	8.04
standard deviation	0.31	2.88	4.01	6.50	4.34	8.10
Festuca idahoensis						
mean	18.77	29.12	48.18	54.33	43.42	66.82
standard deviation	15.74	13.96	20.78	30.39	23.66	29.69
Stipa richardsoni						
mean	0.84				4.87	5.64
standard deviation	1.74				5.18	6.13
Miscellaneous grasses						
mean	4.44	5.81	14.03	18.60	13.38	6.33
standard deviation	4.13	6.02	8.47	12.10	14.78	9.73
			Forbs			
Achillea millefolium						
mean	1.01	1.95	2.68	2.09	8.72	2.81
standard deviation	0.66	1.70	3.16	2.12	26.25	2.14
Agoseris sp.						
mean	1.34	3.41	5.09	6.21	3.42	4.64
standard deviation	3.16	5.49	7.73	10.45	7.04	9.10
Arenaria congesta						
mean	2.47	3.36	6.40	6.45	6.60	6.67
standard deviation	2.94	3.18	4.39	4.76	6.72	4.92
Cerastium arvense						
mean	0.12	2.51	4.85	5.13	7.57	5.37
standard deviation	0.30	4.75	5.03	9.60	14.79	6.12

Table 2. (Continued).

Species	Date of Sample					
	15 June	30 June	13 July	27 July	9 August	24 August
Forbs (Continued)						
Erigeron speciosus						
mean			1.70	7.31	7.57	13.82
standard deviation			4.34	7.19	9.20	20.38
Galium boreale						
mean	0.12	2.51	4.85	5.13	7.57	5.37
standard deviation	0.30	4.75	5.03	9.60	14.79	6.12
Lupinus argenteus						
mean	0.21	12.64	19.64	42.10	42.72	23.54
standard deviation	0.54	10.91	14.48	31.35	33.47	20.25
Miscellaneous forbs						
mean	8.69	16.09	19.82	12.54	8.92	10.28
standard deviation	3.62	10.53	6.98	9.50	11.60	9.37
Standing dead						
mean	7.24	4.07	2.75	1.69	0.23	0.27
standard deviation	8.49	3.88	2.39	2.53	1.05	0.58
Total live and dead						
mean	56.17	106.48	161.01	200.71	201.10	201.00
standard deviation	50.28	80.62	104.98	64.20	81.70	37.20

Table 3. Bimonthly vegetational standing crop, Bangtail Mesa Site (1971), control plot (replicate 1) in g dry wt/m^2.

Species	Date of Sample					
	15 June	30 June	13 July	27 July	9 August	24 August
			Grasses			
Agropyron subsecundum						
mean	11.87	23.67	23.83	41.59	34.87	35.51
standard deviation	6.67	11.13	19.08	32.87	37.78	48.40
Carex sp.						
mean	1.72	2.02	1.86	4.60	3.57	6.91
standard deviation	3.44	3.14	2.08	6.67	4.26	11.23
Danthonia intermedia						
mean	0.08	2.52	4.62	6.34	4.14	8.35
standard deviation	0.20	2.52	4.62	6.34	4.14	8.35
Festuca idahoensis						
mean	29.56	19.48	39.88	47.10	39.08	70.15
standard deviation	21.52	8.71	14.97	15.24	17.63	34.08
Stipa richardsoni						
mean	0.72				7.10	2.84
standard deviation	2.28				6.24	4.41
Miscellaneous grasses						
mean	7.48	6.14	16.28	21.83	19.25	2.44
standard deviation	5.35	6.16	9.81	11.84	19.34	3.47
			Forbs			
Achillea millefolium						
mean	1.00	2.04	2.51	2.09	15.76	1.97
standard deviation	0.70	1.84	2.78	2.20	37.10	1.67
Agoseris sp.						
mean	1.82	3.53	5.40	9.30	5.14	4.40
standard deviation	3.81	5.59	7.16	12.15	9.35	10.42
Arenaria congesta						
mean	2.55	2.58	5.31	4.26	5.72	6.95
standard deviation	3.69	2.43	3.60	2.30	4.73	3.80
Cerastium arvense						
mean	0.82	1.84	5.21	8.40	4.48	7.11
standard deviation	0.92	2.23	1.88	4.20	2.91	2.32

Table 3. (Continued).

Species	Date of Sample					
	15 June	30 June	13 July	27 July	9 August	24 August
			Forbs (Continued)			
Erigeron speciosus						
mean			0.87	10.02	6.21	15.99
standard deviation			1.72	8.74	7.59	27.17
Galium boreale						
mean	0.24	1.84	5.21	8.40	4.48	7.66
standard deviation	0.42	2.77	5.50	13.14	9.24	7.07
Lupinus argenteus						
mean	0.42	8.62	13.66	34.36	34.84	18.14
standard deviation	0.77	10.09	6.13	22.42	29.61	21.14
Miscellaneous forbs						
mean	10.06	12.77	24.35	11.24	7.41	11.90
standard deviation	3.34	4.78	7.35	5.51	11.09	12.26
Standing dead						
mean	13.60	4.37	3.06	2.14		0.09
standard deviation	11.95	5.01	2.13	3.34		0.21
Total live and dead						
mean	81.94	91.51	151.91	207.87	190.34	194.23
standard deviation	65.06	66.40	88.81	146.96	201.01	196.00

Table 4. Bimonthly vegetational standing crop, Bangtail Mesa Site (1971), control plot (replicate 2) in g dry wt/m^2.

Species	Date of Sample					
	15 June	30 June	13 July	27 July	9 August	24 August
			Grasses			
Agropyron subsecundum						
mean	7.00	16.83	22.79	13.03	41.06	45.53
standard deviation	3.30	7.66	17.69	5.71	61.86	30.30
Carex sp.						
mean		4.51	5.16	4.32	9.76	1.23
standard deviation		7.30	3.64	6.59	9.62	1.68
Danthonia intermedia						
mean	0.16	2.26	5.40	11.82	5.81	8.71
standard deviation	0.40	3.19	3.30	6.66	4.53	7.83
Festuca idahoensis						
mean	7.99	38.76	56.48	61.55	47.77	63.50
standard deviation	5.68	17.72	25.29	40.19	28.44	24.53
Stipa richardsoni						
mean	0.95				2.65	8.45
standard deviation	0.95				3.85	7.47
Miscellaneous grasses						
mean	1.39	5.48	11.79	15.37	7.51	10.23
standard deviation	2.33	5.87	1.87	12.37	7.93	13.31
			Forbs			
Achillea millefolium						
mean	1.01	1.87	2.85	2.09	1.68	3.66
standard deviation	0.61	1.55	3.50	2.03	1.28	2.52
Agoseris sp.						
mean	0.87	3.29	4.79	3.11	1.69	4.89
standard deviation	2.34	5.40	8.26	8.40	3.44	7.54
Arenaria congesta						
mean	2.39	4.14	7.49	8.64	7.48	6.40
standard deviation	1.90	3.78	5.05	6.32	8.24	5.83
Cerastium arvense						
mean	0.43	1.32	3.00	2.21	5.38	2.34
standard deviation	0.99	2.05	1.82	3.29	9.40	1.66

Table 4. (Continued).

Species	Date of Sample					
	15 June	30 June	13 July	27 July	9 August	24 August
Forbs (Continued)						
Erigeron speciosus						
mean			2.53	4.61	8.93	11.66
standard deviation			5.89	5.21	10.57	9.59
Galium boreale						
mean		3.18	4.50	1.87	10.67	3.08
standard deviation		6.12	4.51	3.41	18.77	5.00
Lupinus argenteus						
mean		16.67	25.63	49.83	50.61	28.94
standard deviation		11.67	19.53	38.24	36.93	19.31
Miscellaneous forbs						
mean	7.31	19.42	15.29	13.84	10.42	8.66
standard deviation	3.88	14.11	6.60	12.26	12.09	5.03
Standing dead						
mean	0.88	3.76	2.45	1.23	0.47	0.45
standard deviation	1.13	2.23	2.62	1.28	1.48	0.79
Total live and dead						
mean	30.38	121.49	170.15	193.52	211.89	207.73
standard deviation	23.51	88.65	114.57	151.96	218.43	142.39

Table 5. Temperature records for week no. 23 to 36 for the Bangtail Mesa Site (1969, 1970, 1971).

Year	June			July					August				September	
	23	24	25	26	27	28	29	30	31	32	33	34	35	36
						Air (°F)								
Average max														
1969														
1970				67	70	69	63?	68	73	71	71	73		
1971		53	60	47	58	61	62	57	73	72	70	68	52	59
Average min														
1969														
1970				43	54	49	48	48	54	49	49	53		
1971		39	40	34	33	31	44	37	50	50	47	47	36	39
Absolute max														
1969														
1970				76	76	75	78	72	80	79	75	79		
1971		66	69	60	67	70	68	67	76	75	74	73	63	64
Absolute min														
1969														
1970				29	41	36	37	42	42	38	38	47		
1971		36	32	28	26	32	38	31	47	48	42	41	28	33
						Soil (°C)								
Average max (10 cm)														
1969														
1970										16	19	20		
1971		13	15	--	14	15	15	14	17	18	17	16	13	12
Average min (10 cm)														
1969														
1970						9	8	8	--	10	13	14		
1971		9	11	--	9	11	16	10	12	13	12	12	10	8
Average max (50 cm)														
1969														
1970					10	12	13	13	13	13	13	14		
1971		3	5	--	4	5	6	5	7	9	8	7	6	

Table 6. Precipitation, wind, and soil water data for week no. 23 to 35 for the Bangtail Mesa Site Station (1969, 1970, 1971).

Year	June			July				August					
	23	24	25	26	27	28	29	30	31	32	33	34	35
Precipitation (cm)[a]													
1969													
1970				1.47	2.06	3.54	2.39	0.29	0.11	0.01	0.00	1.00	
1971		5.70[b]		1.20	tr	tr	tr	1.90	tr	0.06	tr	4.80	4.10
Wind Average (miles per hour)													
1969													
1970				4.8	5.0	5.2	5.6	4.2	5.0	6.9	5.0	6.9	
1971				6.0	6.4	5.2	5.0	4.2	4.7	5.1	5.6	5.8	5.6
Soil Water (bars)													
10 cm depth[c]													
1969													
1970					0.24	0.25	0.26	0.26	1.74	10.10	14+	14+	14+
1971		0.00	0.00	0.25	0.24	2.48	2.99	14+	14+	14+	14+	14+	0.52
25 cm depth													
1969					0.24	0.26	0.26	0.25	0.54	3.97	12.72	14+	14+
1971		0.00	0.00	0.27	0.25	0.37	9.95	12.45	14+	14+	14+	14+	2.75
75 cm depth													
1969													
1970					0.24	0.24	0.25	0.26	0.25	0.20	0.50	0.75	1.70
1971		0.00	0.00	0.27	0.25	0.22	0.22	0.26	0.82	7.94	11.72	14+	14+

0.00	0.00
0.00	0.00
7.50	

[a] Wind and precipitation were also read Wednesdays and are recorded in the preceding week.

[b] 15 June to 1 July.

[c] Soil water values were read on Wednesday of the specified week; the average of 10 blocks (Controls 1 and 2) are given.

Seasonal conditions. The growing season of 1971 was drier and slightly warmer than average (Tables 7 and 8). Preseason precipitation differences are unimportant since the soils were saturated in June.

Preliminary Synthesis

Standing dead material is highest (over 100 g/m^2) in September when most of the annual production enters this class. By early June it has declined to less than 30 g/m^2. The decline continues throughout the summer reaching 6 g/m^2 in early July and less than 1 g/m^2 by mid-August (Table 9).

Litter remains nearly constant throughout the year at about 60 g/m^2. Decomposition rates in the standing dead and litter compartments must equal (approximately) the loss from the standing dead compartment, about 8 g/month in the snowy season and over 4 g/month in the summer. Data being gathered now in a litter bag study should substantiate these figures and clarify the seasonal variation in decomposer activity (Table 9).

Apparent primary production is 160 and 200 g/m^2/year in 1970 and 1971, respectively. These values are the maximal standing crops and do not take into account the amount of production dropped into the litter layer by early August by spring producers such as *Anemone, Claytonia, Delphinium, Mertensia, Microsteris, Myosotis, and Ranunculus.* In both years most of the material was produced before 1 August; half was produced by mid-June in 1970, but in 1971 half of the material was not produced until 1 July. Production of major species (Tables 2, 3, 4, and 9) parallels total production (50% by 1 July and nearly 100% by 1 August); miscellaneous grasses and forbs tend to produce earlier, and *Erigeron speciosus* is a late producer.

The 40 g/m^2 increase in total primary production of 1971 over 1970 is significant in the "real" as well as the statistical senses since due to

Table 7. A comparison of 1971 rainfall and average temperatures with those of an average year (60-year record) at the college station, Bozeman, Montana.

Month	Precipitation		Temperature	
	Average	1971	Average	1971
May	2.97	2.20	50.1	52.2
June	2.90	2.86	57.4	58.0
July	1.27	0.29	65.2	65.1
August	1.12	0.70	64.0	70.9
September	1.65	2.41	54.3	52.2

Table 8. Comparison of monthly temperature and precipitation records with the 30-year average, Montana State college station (1968, 1969, 1970, 1971).

Month	Precipitation (inches)					Mean temperature (°F)				
	Average	1968	1969	1970	1971	Average	1968	1969	1970	1971
January	0.90	0.91	1.95	0.70	0.96	20.3	20.8	15.7	24.3	24.6
February	0.74	0.44	0.44	0.32	0.78	23.8	28.4	22.2	34.7	29.7
March	1.52	2.13	0.46	2.21	0.74	30.1	38.1	26.9	29.5	32.0
April	1.73	1.42	2.51	1.55	2.82	42.2	38.8	46.6	35.6	41.2
May	2.34	4.03	1.92	3.42	2.20	52.5	47.1	54.4	51.9	52.2
June	2.95	3.78	7.37	1.48	2.86	57.7	57.1	56.1	62.2	58.0
July	1.14	1.08	1.70	3.15	0.29	66.4	66.4	65.6	68.0	65.1
August	1.10	2.63	1.50	0.97	0.70	64.9	60.7	67.8	69.0	70.9
September	1.57	2.77	0.86	2.23	2.41	55.8	53.4	59.1	51.4	52.2
October	1.40	1.37	3.02	1.58	0.65	46.0	43.7	38.2	42.0	42.4
November	1.05	2.65	0.58	1.41	0.77	35.5	30.8	36.4	33.7	33.4
December	0.87	0.35	1.09	0.62	0.56	22.2	18.8	28.5	23.8	20.9
TOTAL	17.31	23.56	23.40	19.64	23.40					

Table 9. Comparison of 1970 and 1971 Bangtail Mesa Site biomass measures (g/m^2).

Vegetation and Species	1970 Dates: 22 June	8 July	20 July	3 August	17 August	31 August
	1971 Dates: 15 June	30 June	13 July	27 July	9 August	24 August
Standing dead						
1970	35.6 ± 15.7	6.9 ± 7.9	5.7 ± 7.5	5.9 ± 8.3	0.7 ± 1.1	20.7 ± 13.5
1971	7.3 ± 8.5	4.1 ± 3.1	2.8 ± 2.4	1.7 ± 2.5	0.2 ± 1.1	0.3 ± 0.6
Litter						
1970	82.9 ± 76.9	152.5 ± 115.8	65.3 ± 65.4	67.8 ± 37.6	122.2 ± 54.7	43.9 ± 25.6
1971	46.3 ± 25.2	50.5 ± 31.9	50.2 ± 22.7	60.0 ± 28.8	56.5 ± 28.6	41.6 ± 18.0
Live and standing dead						
1970	98.8 ± 22.5	116.7 ± 47.8	150.1 ± 40.3	159.9 ± 41.0	122.3 ± 30.8	113.9 ± 46.9
1971	56.2 ± 50.3	106.5 ± 80.6	161.0 ± 105.0	200.7 ± 64.2	201.1 ± 81.7	201.0 ± 37.2
Festuca idahoensis[a/]						
1970	19.6 ± 10.4	28.0 ± 14.4	34.0 ± 14.5	35.6 ± 19.8	44.1 ± 18.0	31.3 ± 12.9
1971	18.8 ± 15.7	29.1 ± 14.0	48.2 ± 20.8	54.3 ± 30.4	43.4 ± 23.7	66.8 ± 29.7
Agropyron subsecundum						
1970	9.4 ± 5.3	20.3 ± 9.6	23.3 ± 18.4	27.3 ± 23.6	38.0 ± 51.3	40.5 ± 40.4
1971	9.7 ± 4.5	23.3 ± 14.6	22.5 ± 24.9	24.8 ± 17.9	22.7 ± 25.9	19.7 ± 19.4
Danthonia intermedia						
1970	1.5 ± 2.0	2.9 ± 4.7	5.2 ± 4.2	7.6 ± 7.7	3.4 ± 2.9	2.3 ± 1.8
1971	0.1 ± 0.3	2.4 ± 2.9	5.7 ± 4.0	8.6 ± 6.5	5.2 ± 4.3	8.0 ± 8.1
Lupinus argenteus						
1970	4.3 ± 4.2	14.1 ± 10.2	18.9 ± 16.9	23.9 ± 26.9	13.4 ± 11.4	13.2 ± 16.2
1971	0.2 + 0.5	12.6 ± 10.9	19.6 ± 14.5	42.1 ± 31.4	42.7 ± 33.5	23.5 ± 20.3

[a/] Species listed include standing dead.

the randomized block design each 1971 clipped plot was within feet of its sister 1970 plot and since the same clipping crew was used. June production (about 100 g/m^2) was similar in both years; July production was about 60 g/m^2 in 1970 and about 100 g/m^2 in 1971, and August production was nil in both years. The following summarizes environmental information which might bear on the change in productivity:

1. Mineral and CO_2 availability should have been similar in both years since the site is the same and litter loss apparently equals litter decomposition.

2. Average maximum and minimum air temperatures were lower for all weeks in July of 1971 than in 1970; unless growth is inhibited by temperature highs of 75 to 80°F, greater growth would have been expected in 1970 than in 1971 (Table 8).

3. Soil water became limiting (over 3 bars) in the upper 30 cm of soil during week 32 (2nd week of August) in 1970 and during week 29 (3rd week of July in 1971). Deep soil water (75 cm) became limiting during week 32 in 1971, and was never limiting in 1970. One might conclude that (i) 1971 growth was limited in late July by a lack of water and (ii) since water was available in early August of 1970 when no growth was observed, that the growth of most plants was restricted by some factor other than water. A pilot study of photoperiodic restriction is in progress (Table 6).

4. Evaporative stresses should have been similar in both years since wind flows, solar radiation, and temperatures were similar.

5. No good measure of solar radiation is available for 1970. Table 10 suggests that solar radiation was lower in July of 1970 than in July of 1971.

6. *Microtus montanus* populations declined sharply in 1971 from 6.8 individuals/ha in 1970 (Hoffmann, 1971; Grant, 1971*b*) to 0 individuals/ha

Table 10. Cloud cover at Bozeman Airport (1968, 1969, 1970, 1971).[a/]

		Cover (tenths)			
		0 (Clear)	1 to 5 (Scattered)	6 to 9 (Broken)	10 (Overcast)
April	1968	--	--	--	--
	1969	5	4	10	11
	1970	1	4	8	17
	1971	2	3	10	15
May	1968	--	--	--	--
	1969	4	9	14	4
	1970	3	7	11	10
	1971	1	8	10	12
June	1968	4	6	8	12
	1969	3	11	7	9
	1970	6	6	13	5
	1971	2	8	9	11
July	1968	11	9	9	2
	1969	11	12	5	3
	1970	7	10	11	3
	1971	11	13	4	3
August	1968	15	6	8	2
	1969	16	9	4	2
	1970	13	13	3	2
	1971	7	10	11	3

[a/] Cover was read at 2 PM each day in tenths of total sky. In this table the number of days with a given sky cover per month is summarized.

in 1971; only one individual was caught in 3456 trap nights (total for the four trapping periods) spent on the 2.76-ha (snap trap) grid studied by Hoffmann. Two other individuals were caught on three other similar grids not trapped in 1970 (3600 trap nights each). Gopher (*Thomomys talpoides*) numbers in 1971 were similar to those of 1970 (4.5 individuals/ha); gopher mounds counted in a 2.76-ha area were 340 in 1970 and 317 in 1971. Changes in other herbivores were neither measured nor noted subjectively. Diptera (biting flies) seemed less plentiful in 1971 than in 1970.

In summary, temperatures and perhaps precipitation should have favored high primary production in 1970, while solar radiation and small *Microtus* populations might have favored high primary production (or apparent primary production) in 1971. Further analysis of the data and probably additional data will be required to explain why 1970 production was only 80% of 1971 production.

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