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PRIMARY PRODUCTIVITY OF THE FESCUE GRASSLAND IN WESTERN MONTANA

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GRASSLAND BIOME

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TABLE OF CONTENTS

ABSTRACT

A study of primary productivity in the Fescue Grassland in western Montana was conducted on the National Bison Range northwest of Missoula, Montana in 1970. A comparison of two vegetation conditions was made. They are: a stand dominated by a rough fescue (*Festuca scabrella* Torr.) with a grazing history of light to no use in most years and a mixed stand of Idaho fescue (*F. idahoensis* Elmer) and bluebunch wheatgrass [*Agropyron spicatum* (Pursh) Scrib. and Smith] with a grazing history of moderately close use and both stands on comparable sites. Air and soil temperatures, relative humidity, precipitation, wind velocity, and soil moisture characteristics of the environment were monitored. Height growth, plant moisture content, and phenology were recorded. Biweekly harvesting of .5 m^2-plots was initiated in April and continued to October. Separation of aboveground plant biomass components was made, including 1970 standing green, 1970 standing dead, and 1969 standing dead and litter. Moss and below-ground plant biomass were single date determinations. Total plant biomass was 3170 and 1728 g/m^2 for the light and moderately close grazed treatments, respectively. Net primary production was 531 and 298 g/m^2, respectively. While growth is initiated in the fall of the previous year, significant spring growth requires daily mean temperatures of over 5°C. Soil moisture stress at -15 bars terminated growth by July 3 under both treatments. Efficiency in utilization of precipitation is a more realistic measure of the use of the environmental resources than use of radiant energy.

INTRODUCTION

The requirements for adequate protection and use of renewable resources, such as our natural grasslands, demand a more thorough understanding of the dynamics of these ecosystems. The efficient use of incoming radiation, precipitation, and soil fertility is essential. An understanding of the driving and regulating forces of the environment must be reached. Information on primary productivity, including plant biomass, standing crop, and net primary productivity, are necessary reference values in using and testing management systems.

The Fescue (*Festuca scabrella* Torr.) Grassland is considered to be one of the major grassland associations of the North American continent (Moss 1955, Coupland 1961). While long considered a part of the Palouse Prairie (Weaver and Clements 1929), the dominant species exhibits a distinctive physiognomy and has many associates not commonly found in typical Palouse Prairie. The distribution of the Fescue Grassland from the valleys of western Montana to Alberta and Saskatchewan in Canada represents a phase of the Grassland Biome of sufficient importance to evaluate from a productivity standpoint and to contribute to our understanding of the Grassland Biome.

As additional background, this association makes contact with both Idaho fescue (*F. idahoensis* Elmer) and bluebunch wheatgrass [*Agropyron spicatum* (Pursh.) Scrib. and Smith] dominant communities at lower elevations, and ponderosa pine (*Pinus ponderosa* Dougl.), Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), and lodgepole pine (*P. contorta* Loudon), forest communities at the upper elevation in western Montana. On the east side of the Rocky Mountains in Montana and Canada it makes contact with the Mixed Prairie Assoc. at

lower elevations and with a variety of forest communities at upper elevations. While many elements of the associated grasslands occur in the Fescue Grasslands, several species of *Danthonia* and *Stipa*, as well as *Helictotridhon hookeri* (Scrib.) Henr. and *Bromus inermis* ssp. *pumpellianus* (Scrib.) Wagnon, are associated with rough fescue. The particular location is a dry phase of the Fescue Grassland and lacks these species. A grazing disclimax community dominated by Idaho fescue is recognized and may be extensively distributed over a range of elevations.

THE STUDY AREA

The National Bison Range (Morris 1970) located in western Montana some forty miles northwest of Missoula contains a variety of grassland stands. Two were selected for the productivity study: a rough fescue dominated stand on an area having a history of light to no grazing which represents near climax conditions and a stand dominated by Idaho fescue and bluebunch wheatgrass which represents a history of moderately close grazing. The stands were enclosed with game-proof fences before the 1970 growing season. They are each approximately 1.62 ha (4 acres) in size. Because of the open range character of the National Bison Range, comparable treatments in close proximity were impossible to obtain. Differentials in grazing pressure due to water, topography, and working requirements have yielded patterns of cover modification, and these were sought out. Soil type, slope intensity, and exposure have been approximated. Meteorological data and soil moisture supply records indicate reasonable comparability. Likewise, studies on the game range and elsewhere on plant succession

and productivity under various degrees of grazing pressure support the selection and characterization of the stands. See Tables 1, 2, 3, 4, and 5 for evidence on comparability of the two treatment locations with respect to species, precipitation, air temperature and soil moisture (-15 bar).

The layout of replications and sampling dates was done in a stepwise randomization pattern. The location of sample plots within a harvest date location was systematic (Fig. 1 and 2). Plots were square and 70 cm on a side, i.e., .5 m^2 in area. Harvesting was generally at biweekly intervals. On most of the sampling dates, 10 plots were taken per replicate. Standing plant material was clipped to the soil surface and sorted by species in the field, except for the various bluegrasses and prairie June grass [*Koeleria cristata* (L.) Pers.], which were grouped. Annual grasses were also grouped, as well as some forbs, mostly annual.

Earlier in the season plastic sacks were used for collection and weighing. For most of the season, paper sacks were used and samples arranged on racks for ventilation of samples. They were subsequently oven dried at 60°C in the laboratory and weighed. A representative sample of the primary grass species was collected for moisture content. From 15 to 30 plants made up the aggregate sample, depending on the size of the individual plants of each species. Maximum leaf height was also measured from a sample of 25 to 50 plants of rough fescue, Idaho fescue, and bluebunch wheatgrass, except the last species was not easily found for such measurement in the exclosure with a history of light to no grazing. General notes were taken on phenology in addition to the standard plot records of the

Table 1. Botanical comparison of the two treatment locations, one having a grazing history of light to no grazing and the other with moderately heavy or close grazing, on the basis of herbage production by species for 1970.

Species	Past Grazing History			
	No Grazing		Heavy Grazing	
	g/m^2	%	g/m^2	%
Grasses				
Festuca scabrella	140.7	55.65	10.2	6.86
F. idahoensis	10.3	4.07	32.4	21.76
Agropyron spicatum	3.1	1.22	28.5	19.14
Misc. perennial grasses[a/]	2.7	1.06	9.6	6.44
Misc. annual grasses[b/]	6.3	2.49	9.1	6.11
SUBTOTAL	163.1	64.52	89.8	60.31
Forbs				
Lupinus sericeus	41.3	16.33	20.7	13.90
Achillea millifolium	7.8	3.08	7.9	5.31
Lithospermum ruderalae	9.6	3.79	p[d/]	
Geumtriflorum	5.6	2.21	p	
Agoseris glauca	4.8	1.89	4.9	3.29
Arnica fulgens	4.7	1.85	3.7	2.49
Hierocium albertinum	1.3	.51	p	
Castelleja sulfurea	1.8	.71	2.9	1.95
Antennaria rosea	1.1	.43	2.1	1.41
Zigadenus paniculatus	0.5	.19	2.2	1.48
Aster falcatus	p[d/]		5.2	3.49
Misc. forbs[c/]	11.2	4.64	9.5	6.38
SUBTOTAL	89.7	35.48	59.1	39.69
TOTAL (all species)	252.8	100.00	148.9	100.00

a/ Includes *Koeleria cristata*, *Poa pratensis*, *P. secunda*.

b/ Includes *Bromus tectorum*, *B. japonicus*, *Agrostis interupta*.

c/ Includes perennials and annuals, mainly *Erigeron divergens*, *Anaphalis margaritacea*, *Crepis accuminata*, *Saxifraga rhomboidea*, *Tragopogon dubius*, *Collomia*, *Collinsia parvifolia*, *Lithophragma parvifolia*.

d/ p indicates present.

Table 2. Precipitation mean, air and soil temperature mean, relative humidity, and wind conditions at the ungrazed rough fescue treatment location, for periods between herbage production dates.

Period	Precipitation (cm)		Temperature[a/]					Rel. Hum.	Wind
			Air		Soil				
	For Period	Accum.	100 cm	2.5 cm	2.5 cm	25 cm	75 cm	100 cm	100 cm
4/1 - 4/15			4.4						
4/15 - 5/2	1.25	1.25	5.6			7.2	6.8		
5/2 - 5/16	4.04	5.28	14.1	13.9	12.3	8.6	7.3	69.4	1.010
5/16 - 5/30	0.48	5.77	17.0	13.0	9.3	8.6	8.8	60.3	0.956
5/30 - 6/17	5.46	11.23	17.2	12.1	6.7	10.3	10.6	74.8	0.787
6/17 - 7/3	1.35	12.57	20.1	21.2	15.0	13.2	11.1	60.0	0.715
7/3 - 7/16	0.00	12.57	21.2	26.2	17.4	15.5	12.6	57.4	0.997
7/16 - 8/4	1.85	14.43	16.6	17.4	18.4	14.8	13.4	62.9	0.970
8/4 - 8/25	0.00	16.43	20.8	19.4	22.1	15.1	13.8	44.6	1.064
8/25 - 9/26	1.98	16.41	12.4	6.0	9.8	8.6	11.9	60.9	1.202

[a/] Precipitation in cm; temperature in °C and are daily means for period, numerical headings refer to position of the sensor; relative humidity in percent; wind as average daily velocity in m/sec.

Note: 16.26 cm precipitation was recorded at headquarters from September 1969 to April 15, 1970, and may be added to above date, i.e., 32.67 cm for plant growth.

Table 3. Precipitation, mean air temperature, and mean relative humidity at the heavy grazing treatment location, for periods between herbage production dates.[a/]

Period	Precipitation (cm)		Air Temp. °C 100 cm	Rel. Hum. %
	For Period	Accum.		
4/1 - 4/15			5.0[a/]	
4/15 - 5/2	1.25	1.25	4.1	
5/2 - 5/16	5.46	6.71	9.7	68.7
5/16 - 5/30	0.53	7.24	12.6	62.8
5/30 - 6/17	3.02	10.26	13.7	75.0
6/17 - 7/3	1.63	11.89	17.6	57.1
7/3 - 7/16	1.32	13.21	17.9	61.9
7/16 - 8/4	2.52	15.72	14.4	64.7
8/4 - 8/25	0.00	15.72	20.0	48.6
8/25 - 9/26	1.93	17.65	12.1	75.9

[a/] Value for this period obtained from instruments at Bison Range headquarters. Note: 16.26 cm of precipitation was recorded at headquarters from September 1, 1969, to April 15, 1970, and may be added to on site record for approximation of water supply for plant growth of the study period.

Table 4. Soil textural characteristics and moisture retention at a -15 bars for the two plant biomass study areas for 1970. All values in percent.

Soil Depth	Lightly Grazed Area				Moderately Close Grazed Area			
	Sand	Silt	Clay	Moisture at -15 Bars	Sand	Silt	Clay	Moisture at -15 Bars
— cm —	———		%	———	———		%	———
0- 5	24.0	61.6	14.4	26.9	16.0	68.8	15.2	20.0
5- 10	24.4	66.0	9.6	17.8	13.9	62.3	23.8	17.4
10- 20	20.4	70.0	9.6	16.6	15.6	65.6	18.8	17.2
20- 30	22.8	70.2	7.0	16.6	21.6	58.6	19.8	15.0
30- 40	22.0	70.0	8.0	14.8	21.6	61.0	17.4	13.2
40- 50	36.4	49.6	14.0	8.5	35.6	39.0	25.4	13.2
50- 60	28.0	54.8	17.2	5.6	7.6	67.0	25.4	11.4
60- 70	40.0	43.8	16.2	5.7	16.0	62.0	22.0	11.6
70- 80	38.0	46.8	15.2	7.0	-	-	-	10.8
80- 90	64.0	24.8	11.2	4.9	-	-	-	-
90-100	40.0	42.8	17.2	4.6	-	-	-	-

Table 5. Average available soil moisture in the 0-60 cm depth based on -15 bars for the two study locations in rough fescue grassland.

Date	Grazing History	
	Light to None	Closely Grazed
	---------- % ----------	
April 12	-	9.0
April 25	22.3	26.4
May 17	23.0	18.5
May 30	14.0	12.9
June 16	11.4	6.8
July 3	2.7	1.6
July 16	0.2	0.4
July 30	0.1	0.6
August 6	0.0	0.2

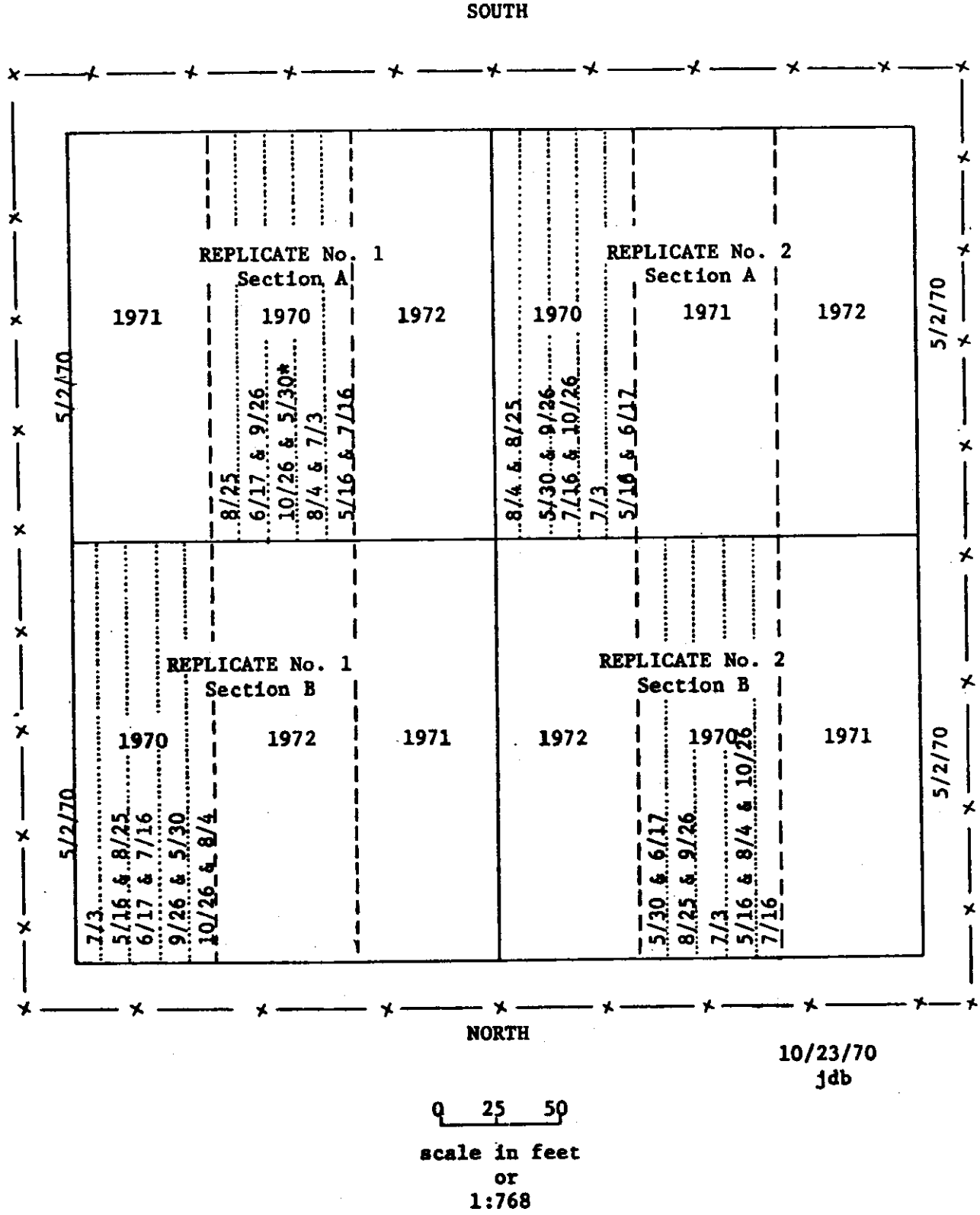

Fig. 1. Layout of replicates and plot lines for the harvesting date used at the light to no grazing treatment location at Bison Site.

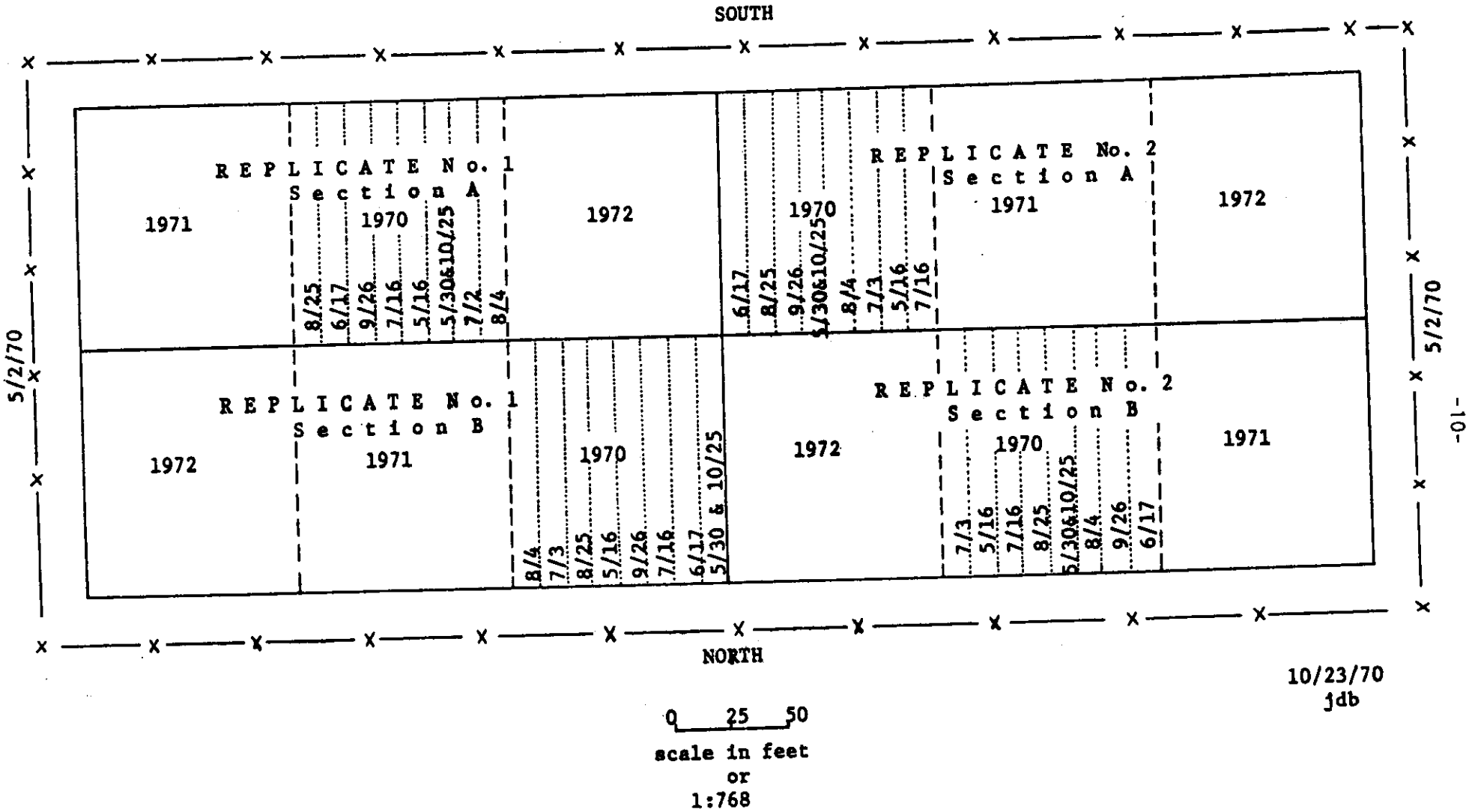

Fig. 2. Layout of replicates and plot lines for the harvesting dates used at the moderately close grazing treatment location at Bison Site.

IBP Grassland Program. The date of full bloom of important species of forbs for the two locations are presented in this paper. One special test on height growth was made for comparability of locations because of a possibility of local wind effect on the growth at the location with climax vegetation. Height growth measurements were made at a location 2.5 miles north and the height values were found to be 2 cm lower than for plants of rough fescue on the particular study area.

Continuous records of air temperature (1 m) and relative humidity were taken at both locations. Continuous records of air temperature at 2.5 cm aboveground and 2.5 and 25 cm in the soil were also recorded at the lightly grazed location. Thermocouple sensors were used at the moderately close grazed location at 2.5 cm aboveground and at 2.5 and 25 cm below the soil surface and were read weekly at approximately 9:00 AM Mountain Standard Time and calibrated with a set at the other location as well as with the recording instrument. Wind records at the first location were cumulative values and read to correspond to the harvesting intervals. Standard rain gages were maintained at both locations. Gravimetric determinations of soil moisture percent were made at biweekly intervals and/or at each harvesting date.

RESULTS OF THE 1970 GROWING SEASON

Abiotic Factors

Precipitation amount and seasonality are generally recognized to be of major importance in the functioning of producer species in a grassland ecosystem. Because records from the study areas were

not started until April, it was necessary to utilize the records from the non-recording rain gage and the maximum-minimum thermometers at the headquarters of the Bison Range. The amount and pattern of precipitation supply was compared to four other stations some distance away and the data show reasonable agreement and warrant their use for evaluating the climatic year of the study. (Appendix Tables 1 and 2).

Because new growth is initiated in early fall if soil moisture is available and continues until the onset of low temperatures in November and December, and because the supply of winter moisture is used to recharge the soil, the climatic year is considered to start in September of one year and to continue through August of the next year. This grouping of months is further justified by what appears to be one of the important observations in this study. The major grasses produced seedstalks abundantly in 1969, but almost completely failed to do so in 1970. Table 6 presents the precipitation and temperature of the climatic year and indicates that the total precipitation was above the longtime average. The difference in the amount of precipitation for September 1968 and September 1969 may account for the difference in the formation of seedstalks. This is certainly in line with the conclusions of Johnston and McDonald (1967) that the fall months are the time of initiation of floral apices of rough fescue. The precipitation data suggests that September moisture may be most critical for seedstalk production. Anslow (1965) stresses the phasic nature of plant behavior in response to changes in the physical environment.

Table 6. Monthly precipitation and mean temperatures for the functional period September to August for 1968-1969, 1969-1970, and longtime averages (Lt. Avg), 20 years, at National Bison Range headquarters.

Precipitation (cm)

Period	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
1968-1969	7.14	1.60	1.50	2.79	6.40	.40	.76	1.30	3.10	13.56	.18	.00	38.74
1969-1970	1.73	2.49	.28	.96	3.91	2.24	2.67	3.45	5.79	5.36	6.45	.58	35.96
Lt. Avg	2.72	2.51	2.08	2.11	2.59	1.49	1.65	2.84	4.17	5.64	2.44	2.31	32.56

Temperature (°C)

Period	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	AVG
1968-1969	12.6	6.2	3.0	-4.6	*	*	-2.6	8.7	11.6	14.7	18.3	15.6	*
1969-1970	13.4	5.4	1.3	-5.4	-3.1	.9	1.9	1.7	11.7	18.3	20.1	19.2	7.1
Lt. Avg	13.5	7.4	1.3	-2.1	-4.0	-.7	1.4	6.8	11.7	15.8	19.4	18.1	7.4

*Missing data.

Temperatures for the period were not excessively high or low, in comparison to the longtime records, except that the mean for April was low. Rough fescue had made 17.1 cm height growth by April 15, with a mean air temperature of 4.4°C taken at 100 cm for the preceding two-week period. This is 35% of the final height growth. On site weather data are presented in Tables 2 and 3 (see Fig. 3 and 4). Soil moisture distribution and availability is presented in Tables 5, 7, and 8. Soil moisture recharge was completed from winter and early spring precipitation. July moisture had little effect on recharge or on plant growth. The downward trend of moisture to a point of unavailability in August is especially significant and helps to characterize the herbage production period as being in the spring and early summer. It is generally recognized that the principal grasses of the Fescue Grassland are cool season species, and greenhouse studies on young plants of rough fescue by Smoliak and Johnston (1968) would support such a generalization.

Air or soil temperature and soil moisture data appear to readily characterize the important environmental factors involved in plant growth and productivity in subhumid to arid grasslands (Smoliak 1956, Blaisdell 1958, Whitman and Walters 1967). Temperature in the spring and early summer acts as a driving force on plant growth (Bentley 1951, Alberda 1966). The height-growth curve follows the rise in temperature until the general growth pattern is developed. Soil moisture supply determines the end of growth and production (see Fig. 5). The soil moisture data is essentially a measure or index of soil moisture stress. It is apparent from the data of this study that soil moisture stress is limiting after July 3 in the upper soil horizons and that

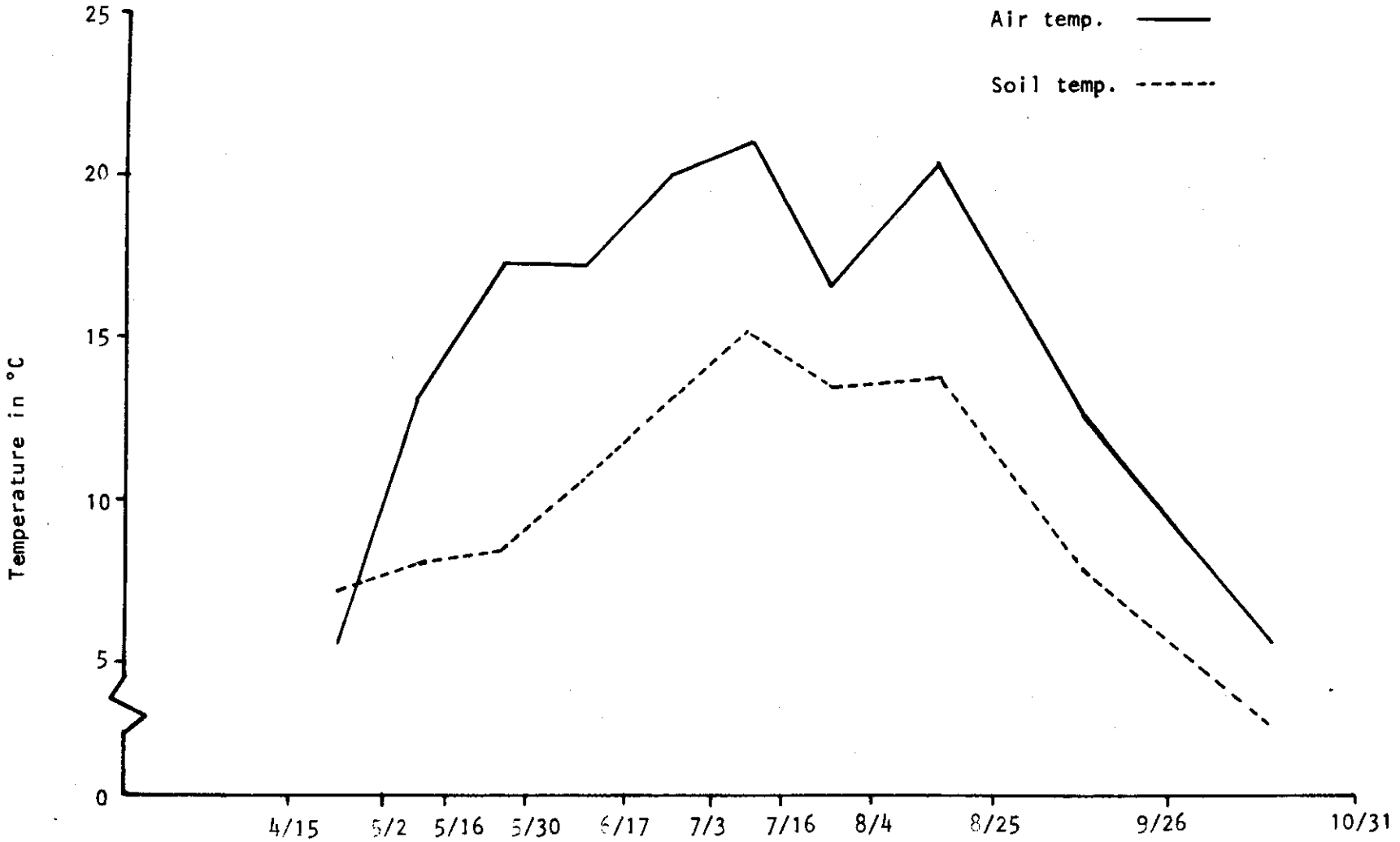

Fig. 3. Mean temperatures for inter-harvesting periods from continuous recording instruments at 1 m above soil surface and 25 cm depth in soil. Light to no grazing treatment location.

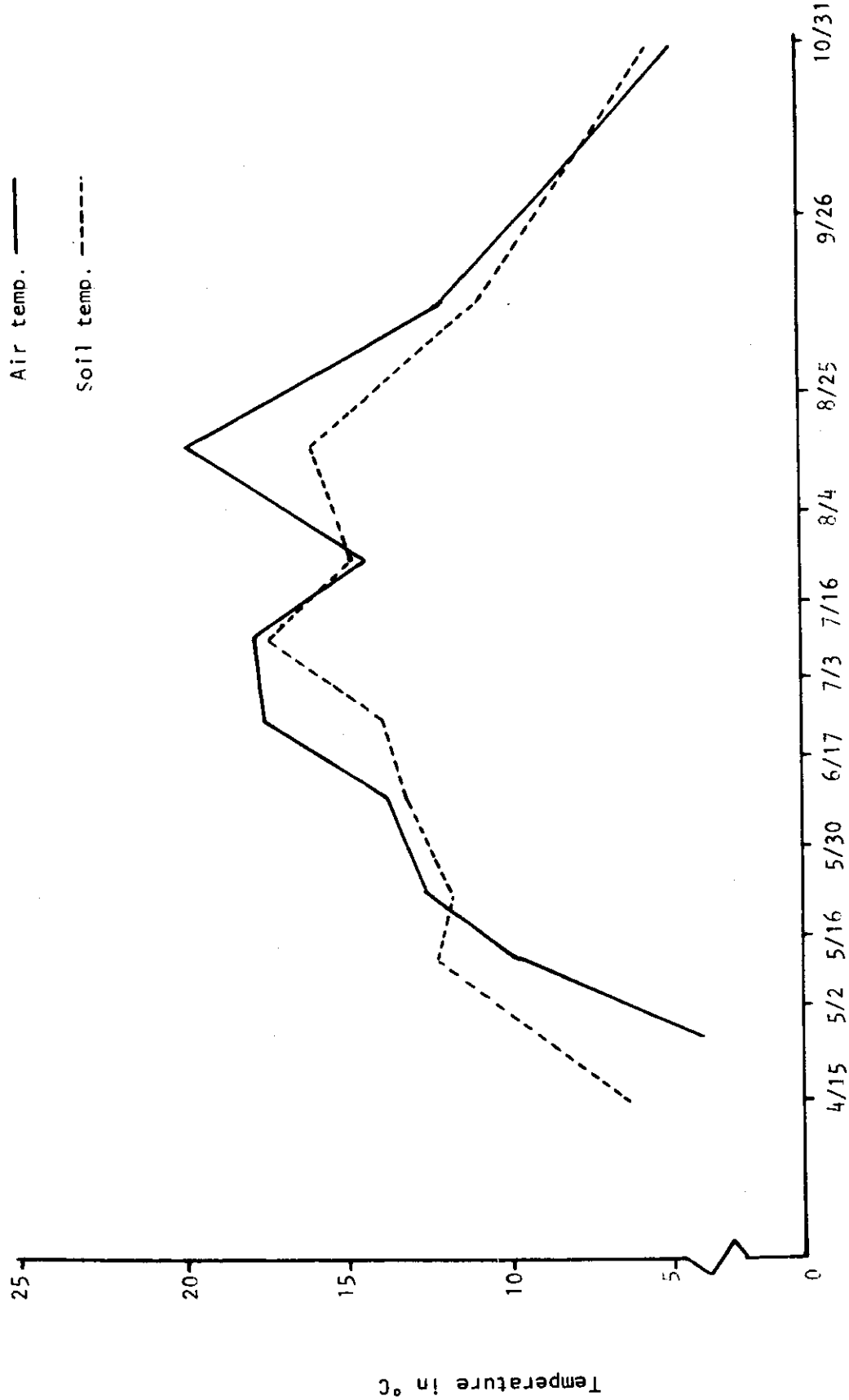

Fig. 4. Mean temperatures for inter-harvesting periods, 1970. Air temperature from continuous recording instrument at 1 m. Soil temperature for 25 cm position from thermocouple readings at 9:00 AM, Mountain Standard Time. Moderately close grazing location.

Table 7. Soil moisture conditions for the 1970 growing season at the location with light to no grazing. Soil moisture determined gravimetrically. Values underscored have available soil moisture (above -15 bars).

Soil Depth	Grazing History -- Light to None												
	4/25	5/17	5/30	6/16	7/3	7/16	7/30	8/6	8/21	8/27	9/17	10/1	10/22
— cm —							%						
0- 5	49.3	55.1	38.0	33.3	26.5	23.0	19.3	14.1	7.4	3.7	16.2	13.7	25.5
5- 10	40.0	43.9	32.4	29.8	22.8	18.6	12.3	9.4	8.1	5.9	10.7	8.6	23.5
10- 20	40.3	44.9	33.8	29.5	23.4	14.0	10.4	9.9	8.0	5.8	7.6	6.8	22.6
20- 30	43.1	43.7	33.8	29.4	21.9	12.7	9.3	9.1	7.5	7.1	7.2	6.0	18.2
30- 40	37.3	36.7	31.8	27.4	20.0	10.4	8.4	7.7	6.4	5.6	6.2	4.1	6.9
40- 50	32.1	26.3	23.2	22.5	12.5	7.7	6.3	5.1	3.6	3.4	4.9	3.1	3.9
50- 60	23.0	19.7	16.4	16.9	11.8	5.6	3.9	4.5	4.2	3.9	3.4	3.6	3.4
60- 70	17.0	11.1	10.3	16.4	9.0	4.9	4.0	3.8	4.6	4.3	3.7	3.7	3.9
70- 80	9.5	9.9	7.5	8.9	8.4	4.7	4.5	3.9	4.2	4.7	4.1		4.1
80- 90	9.0			10.1	11.4	5.5	5.3	4.8	4.3	4.4	4.2		4.8
90-100	8.8					5.6	5.7	5.1	4.9	5.2	4.9		6.4

Table 8. Soil moisture conditions for the growing season at the location with moderately close grazing history. Soil moisture determined gravimetrically. Values underscored have available soil moisture (above -15 bars).

Soil Depth	Grazing History -- Moderately Close Grazing													
	4/12	4/25	5/17	5/30	6/16	7/3	7/16	7/30	8/6	8/21	8/27	9/17	10/1	10/22
— cm —							%							
0- 5	32.9	39.9	40.5	31.3	28.2	18.2	17.7	22.4	15.1	8.1	6.0	15.9	11.9	28.2
5- 10	29.6	33.4	35.0	30.3	25.6	17.0	13.5	17.7	14.1	7.3	8.2	10.6	9.9	27.8
10- 20	25.7	39.2	39.4	31.5	23.2	15.1	10.4	15.5	13.2	6.8	7.1	10.4	8.0	20.5
20- 30	27.9	39.3	36.4	30.0	22.1	12.9	9.9	9.2	11.8	9.2	7.1	6.4	7.6	8.9
30- 40	18.5	22.6	27.8	22.2	16.9	12.9	9.9	8.2	12.2	9.5	6.0	5.5	6.7	5.4
40- 50	17.9	27.7	28.2	24.7	16.6	15.0	14.0	15.6	13.1	10.7	8.1	4.9	5.2	5.4
50- 60	16.2	26.9	29.1	26.1	20.9	19.4	11.7		11.1	9.4	6.9	5.3		
60- 70	14.1	20.4	22.5	24.2	17.3					7.1	7.1	5.9		
70- 80	9.9											6.1		
80- 90	7.4													
90-100	8.5													

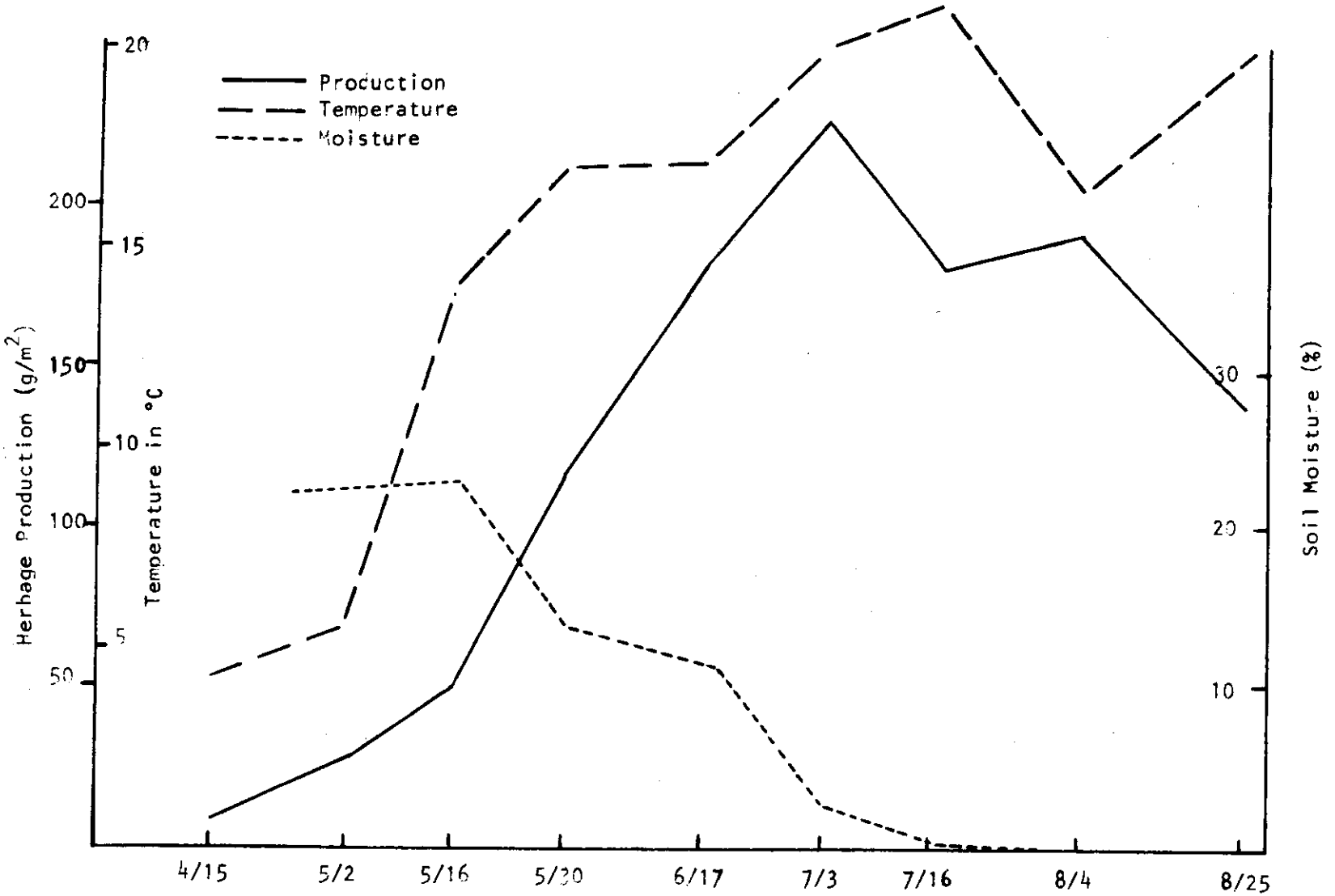

Fig. 5. Trend in net production and standing crop and seasonal trend in mean daily air temperature (°C) at 100 cm and available soil moisture percent averaged for 0-60 cm depth for the treatment light to none for 1970.

it is more completely so in the soils of the treatment area with a history of light to no grazing, while moisture availability is prolonged in the subsoils of the treatment area with a history of moderately close grazing. This difference may be attributed to the functioning of the shallower root system of Idaho fescue in the moderately close grazing area.

The importance of available soil moisture as a major environmental factor limiting plant growth and herbage production is evident from the data. This is shown in Table 5 on available soil moisture, Table 9 on height growth, Table 10 on trend in plant moisture content, Tables 11 and 12 on seasonal trend in 1970 production, and Fig. 5 which shows change in production and standing crop in comparison to change in available soil moisture. The -15 bar moisture tension level provides a satisfactory reference point for understanding one of the limiting factors in controlling plant growth and herbage production in grasslands. This conclusion is consistent with statements of Denmead and Shaw (1962) and Kramer (1969). However, Slayter (1957, 1969) considers plant moisture stress as being a more significant index of environmental stress. In this context, the conclusion made relative to growth and production carries no implication relative to other physiological processes in the plant. It should be added that the trend in height growth showed an earlier slow-up in rate as compared to the trend in production. Shaw and Laing (1965) report on the studies of Hagen and others which support the results in this study. The data suggest that stress appears gradually before growth and production stops. Studies by Woodhams and Kozlowski (1954) also indicate that the stress is a gradual one.

Table 9. Maximum leaf height growth of rough fescue, Idaho fescue, and bluebunch wheatgrass, for the 1970 growing season under two conditions of grazing history.

Treatments[a/] and Species	April 15	May 3	May 15	June 1	June 15	July 1	July 16	Aug. 4	Aug. 15
	cm								
Ungrazed									
Festuca scabrella	17.1	20.6	35.4	44.3	47.4	44.5	44.7	47.5	48.6
F. Idahoensis	6.7	10.1	18.9	22.4	23.5	23.1	23.6	24.0	24.6
Heavily Grazed									
F. scabrella	-	17.0	28.9	27.3	32.3	29.6	32.4	27.3	28.4
F. idahoensis	7.7	12.0	18.4	20.3	20.3	21.3	21.4	19.6	19.2
Agropyron spicatum	7.7	19.9	27.5	34.0	41.5	43.9	43.6	41.3	42.9

[a/] Grazing history follows numerical identification with U.S. IBP Grassland Biome -- 1. (Ungrazed) over a considerable number of years, 2. (Heavily Grazed) moderately heavy grazing until past few years and grazed until 1970.

Table 10. Moisture content of herbage of major grasses at various dates during the 1970 growing season.[a/]

Treatment and Species	4/15	5/2	5/16	5/30	6/17	7/2	7/16	7/30	8/7	8/13	8/20	8/27	9/3	9/17	10/1
	%														
Ungrazed[a/]															
Festuca scabrella	316.6	230.8	164.8	161.4	172.5	142.7	109.1	107.6	66.3	42.3	39.7	30.8	22.9	46.7	36.8
Festuca idahoensis	280.0	173.3	—	134.7	142.8	101.5	75.8	83.5	46.6	42.8	36.8	29.7	23.6	49.7	38.7
Heavily Grazed[b/]															
Festuca scabrella	233.3	161.5	149.8	144.9	155.4	139.7	107.1	99.2	91.1	82.4	78.7	32.5	46.6	57.3	48.6
Festuca idahoensis	252.7	277.8	166.4	157.1	142.5	210.9	67.8	—	61.3	57.2	50.3	51.1	31.6	48.1	43.0
Agropyron spicatum	233.3	195.2	191.6	141.2	142.5	106.3	80.2	72.1	68.9	60.8	62.0	49.9	38.1	47.5	39.5

[a/] Based on oven-dry weights.

[b/] Treatments on U.S. IBP Grassland Biome past code: 1 (ungrazed) and 6 (heavily grazed). None during current season.

Table 11. Seasonal trends of various components of aboveground biomass for two locations in Fescue Grassland with corresponding grazing histories (treatment 1, light to no grazing and treatment 2, moderately close grazing) for the 1970 growing season. Yields in g/m^2.

Biomass Component	g/m^2										
	4/15	5/2	5/16	5/30	6/17	7/2	7/16	8/4	8/25	9/26	10/31
	Grazing History -- Light to None										
Standing Live	8.41	27.42	51.78	117.24	185.63	219.02	168.24	161.03	60.82	27.69	25.95
Standing Dead, 1970	0.00	0.00	0.00	0.00	0.00	9.10	13.34	30.87	78.83	95.37	124.89
Standing Dead, 1969	153.05	140.50	130.73	137.60	91.25	106.63	39.14	46.45	31.53	11.42	0.00
Litter	175.00	180.49	123.67	182.12	146.91	220.30	273.91	329.36	334.57	308.60	243.40
TOTAL	336.46	348.41	306.18	436.96	423.79	555.05	494.63	567.71	505.75	443.08	394.24
	Grazing History -- Moderately Close										
Standing Live	6.98	32.06	46.78	95.75	98.17	97.50	82.14	81.76	43.17	43.29	16.68
Standing Dead, 1970	0.00	0.00	0.00	0.00	0.00	12.19	11.50	20.68	40.19	39.01	61.14
Standing Dead, 1969	56.80	66.89	47.69	62.41	48.52	36.56	20.27	22.82	12.22	1.13	
Litter	55.19	44.79	36.91	26.56	35.92	50.80	73.05	55.51	148.16[a/]	201.82[a/]	110.88[a/]
TOTAL	118.97	143.74	131.38	184.72	182.61	197.05	186.96	180.77	243.36[a/]	285.25[a/]	188.70[a/]

a/ Unexplained.

Table 12. Net productivity and standing crop in terms of grasses and forbs under light to no grazing history as compared to moderately close grazing history for the 1970 growing season. Oven-dry weight basis.

Date	Light to No Grazing			Moderately Close Grazing		
	Grasses	Forbs	Total	Grasses	Forbs	Total
	---------- g/m^2 ----------					
April 15	7.36	1.05	8.41	5.56	1.42	6.98
May 2	16.93	10.49	27.42	17.54	14.52	32.06
May 16	37.39	14.39	51.78	31.05	15.73	46.78
May 30	77.50	39.74	117.24	47.92	47.83	95.75
June 17	115.78	66.78	182.56	58.50	39.71	98.21
July 2	158.33	69.79	228.12	63.44	45.28	108.72
July 16	124.72	56.86	181.58	62.16	34.44	96.60
Aug. 4	148.20	43.70	191.90	74.36	27.76	102.12
Aug. 25	111.33	28.32	139.65	65.85	17.49	83.34
Sept. 26	104.19	18.86	123.06	64.18	18.12	82.30
Oct. 31	117.32	33.52	150.84	---- no data ----		

Data on relative humidity and wind movement appear to be unrelated to the growth and production trends obtained on the two treatment area. They are no doubt contributing to the total loss of soil moisture by evapotranspiration, but as secondary factors, and would be of little aid in the prediction of trend in environmental stress on the vegetation.

GROWTH, PRODUCTIVITY, AND PLANT BIOMASS

Height Growth

The seasonal change in height growth can be important in understanding periodicity of productivity and, in some cases, serve as an index of production as well as for treatment comparisons to express vigor differences. Measurements of maximum leaf height of rough fescue and Idaho fescue were taken biweekly at the two treatment sites. Bluebunch wheatgrass was too infrequent in the ungrazed location, and was measured only in the closely grazed location.

It is surprising that the mean values based on 25 to 50 individuals yield inconsistent values from one date to the next. (See Table 9). However, the discrepancies are small. Initial growth takes place prior to April 15 and is actually initiated in the fall. Height growth change indicates that growth was more or less complete by July 16 and was in a process of slowing down as early as June 1. By April 15, 35% of the height growth on rough fescue had been made and 27% of the height growth on Idaho fescue had been made. A comparison of the same species between treatment areas indicates a difference which may be due to vigor as a result of grazing history. Certainly this is the case for rough fescue. The Idaho fescue measurements on the ungrazed treatment site are confounded by the effect of shading

by rough fescue on Idaho fescue. The Idaho fescue plants are taller, smaller in basal area, and yellow-green in color. An evaluation of the relationship of height to weight will be considered elsewhere on this report.

Height growth is closely related to temperatures in the early spring and early summer. However, once the basic tiller plan has expressed itself, a rise in temperature is not followed by an increase in height growth. It can be said that temperature is an initial driving force. The relationship observed here is similar to the observations of Blaisdell (1958) on bluebunch wheatgrass in Idaho.

Moisture Content

This constituent of plants may serve to indicate plant activity and to provide some measure of association to growth and productivity. The data obtained are presented in Table 10 and follow the pattern of results obtained elsewhere (Wilson, Boggess, and Kramer 1953, and Weinman 1955).

There is a high initial moisture content associated with young leaf tissue, then a sharp downward trend to approximately one-half the early moisture content by the July 3 harvesting. Decline in moisture is less rapid for the remainder of the growing season. The data do not yield a well defined break in trend to correspond with a change in net primary production unless we can infer that, when moisture content drops below 100% of dry weight, no further increase in weight of dry matter can be expected.

These data would suggest that trend in plant moisture content is better associated with production than with a trend in height growth.

Further study along these lines is certainly needed. The breaks in the downward trend in plant moisture content for the period May 30 to June 17 may be due to increased precipitation during this period. The high value for Idaho fescue in the closely grazed treatment for the July 3 determination is not explainable.

It is somewhat hazardous to explain differences between species and locations. Since the moisture determinations were secondary to the production part of the study plan, they were taken after the other work was done. The samples from the closely grazed treatment area were taken in late morning and for the other treatment in late afternoon. While moisture tight plastic sacks were used, some moisture loss was possible. Also, on some days it was difficult to keep the samples cool. The time of sampling probably accounts for the spread between the two locations.

Phenology

The failure of the grasses to develop seedstalks, except for a few Idaho fescue and bluebunch wheatgrass plants on the grazed treatment, was perhaps the major phenological condition of the study. This is in contrast to the very abundant seedstalk development of the previous year. On the other hand, the forbs flowered abundantly. One forb, of scattered distribution on our plots, balsamroot (*Balsamorhiza sagitata* (Pursh) Nutt.), behaved similarly to the grasses.

This periodic failure to produce seedstalks is not uncommon. In this situation it is not related to grazing effect or to litter accumulation, but reflects a phasic influence of the physical environment. While temperature could be a likely factor, it appears to be

related to fall moisture conditions. Johnston and McDonald (1964), in their study of floral apicies development in rough fescue, associate this failure with the lack of fall moisture in that, when the floral apicies do occur, they are observed in the fall growth. From an examination of the precipitation records for the falls of 1968 and 1969 in Table 6, September 1968 had twice the amount of the long-time average, while September 1969 was less than the longtime average.

The effect on litter or herbage dynamics can be of some importance since the old seedstalks of the 1969 season were much in evidence through the 1970 harvesting period. It should also be noted that *Microtus montanus* (Peale) makes a fair amount of use of seedstalks of the fescues on the National Bison Range.

The phenology of general interest is presented in Fig. 6 and 7 and shows the approximate dates of full bloom (percent of plants which flowered is not available, however the flowering was conspicuous). The more common species are presented as well as others which were less abundant in both locations but were of special interest. It should be noted that the species common to the two locations came into full bloom at approximately the same time. There is an orderly progression of early species, late spring species, early summer species, and late summer species. This may involve day length and other phasic phenomenon. Leaf material in the early species enters the litter layer before midsummer. Seedstalks are the most persistent materials. Seedstalks of *Lupinus* and *Achillea* are readily recognizable in the litter layer from previous years growth.

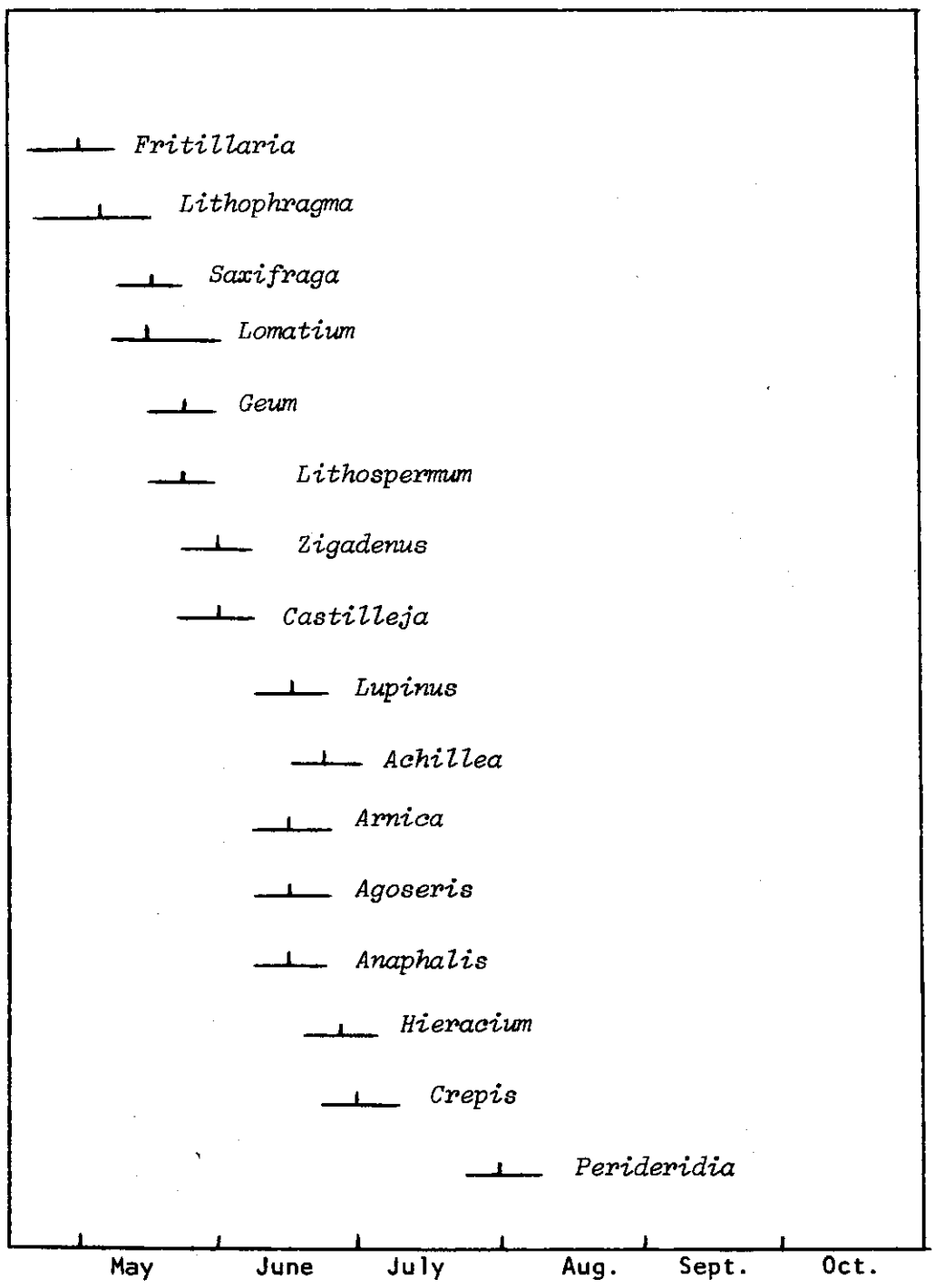

Fig. 6. Approximate dates at which full bloom occurred for several common forbs on the area with history of light to no grazing.

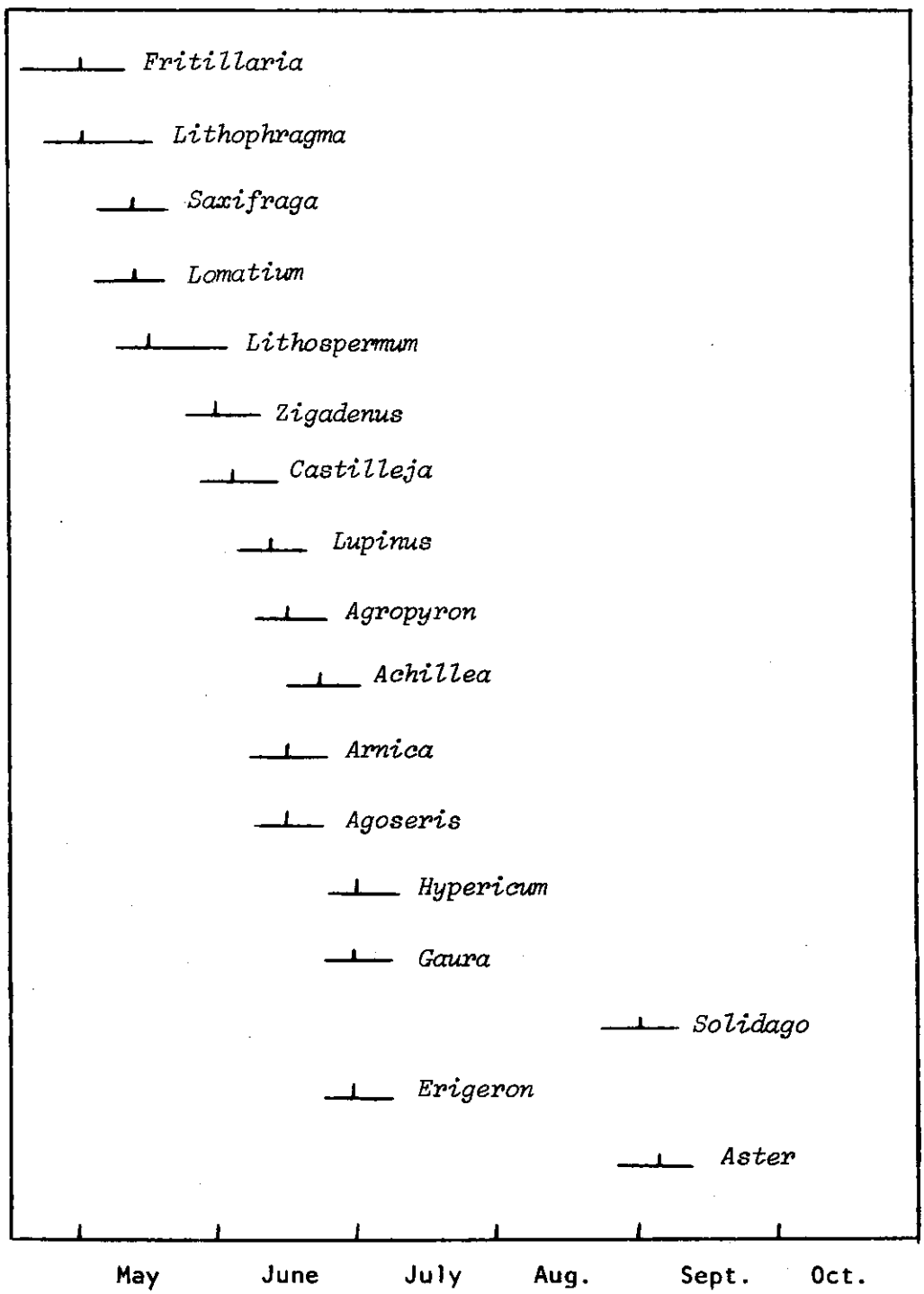

Fig. 7. Approximate dates at which full bloom occurred for several common forbs on the area with history of moderately close grazing.

Seasonal Trends in Aboveground Biomass

Table 11 contains the data on seasonal change in the four major components of aboveground biomass. While growth was initiated in the late fall of 1969, initial harvesting of plots did not take place until April, and the first figures are reported for April 15 which include all the growth made prior to that date. Daily increment of growth to this date must have been quite low. While soil moisture was adequate, mean daily temperatures were close to 5°C (40°F) which is near the threshold value for initial plant growth of cool season species (Maximov 1938), and is in agreement with statements by Friend (1966) and Niciporovic (1968).

The grand period of growth for the ungrazed treatment was between May 15 and July 3, while it was somewhat earlier on the heavily grazed treatment. The maximum rate for both treatment stands was obtained for the May 15 to June 1 period when the daily rate of net productivity was 4.7 g/m^2/day on the light to no use treatment and 3.5 g/m^2/day on the closely grazed treatment (Fig. 8). The total net primary production was reached at the same time, July 3, and was 228.12 g/m^2 on the ungrazed treatment and 109.69 g/m^2 on the closely grazed treatment. The similarity of the primary productivity curve reported here to that of Idaho fescue obtained elsewhere is striking (Price 1955, Hormay and Talbot 1961). The standing crop produced in 1970 declined sharply after July 3 on one treatment, while it declined more slowly on the other treatment. This loss in herbage weight probably is due to several changes, including the earlier maturing forbs going into litter, direct oxidation loss of standing material, and translocation of carbohydrates into the belowground portion of live plant material (roots and root crown).

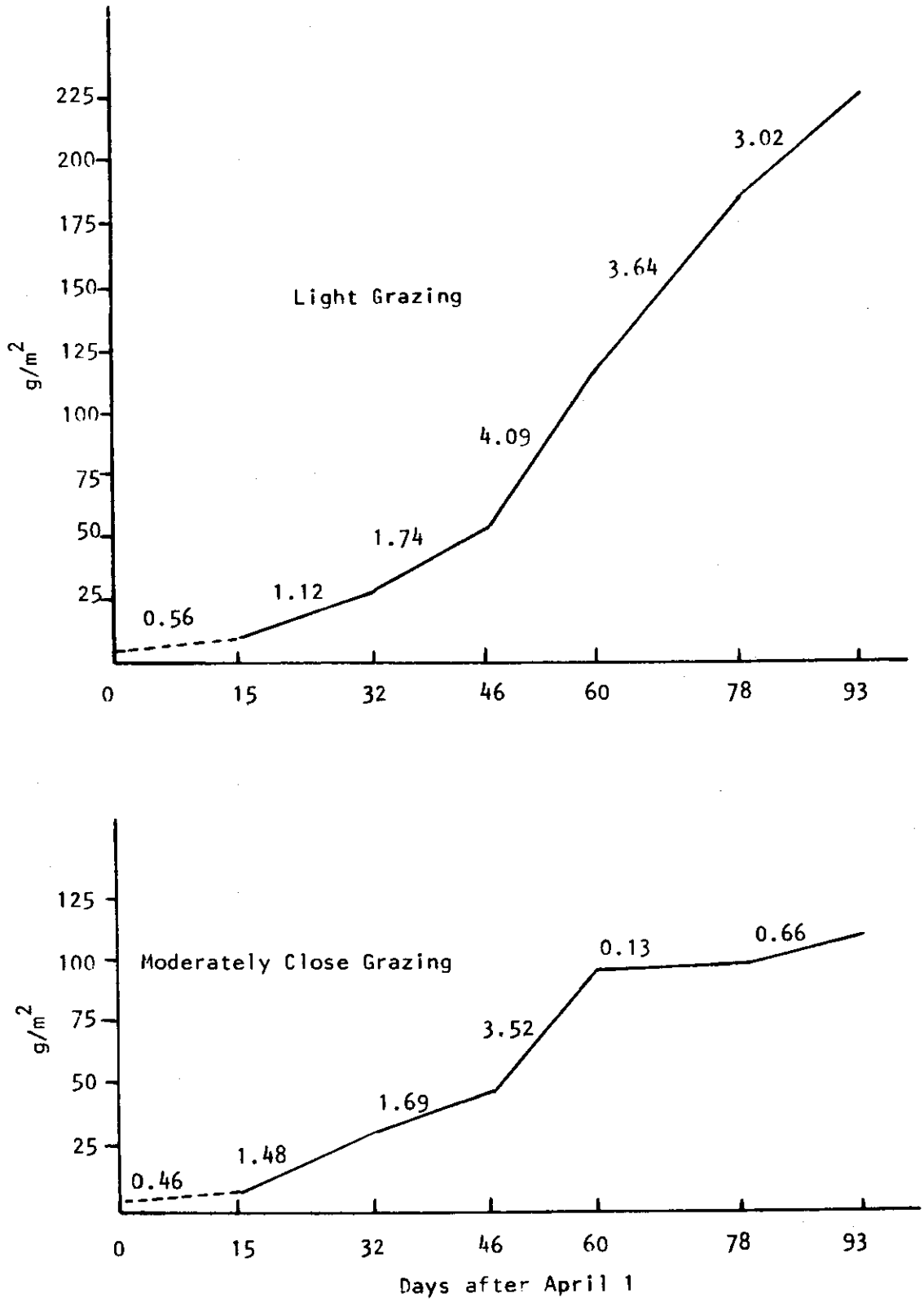

Fig. 8. Daily herbage production rates in grams per square meter for the various harvesting periods expressed in days after April 1, for both treatment locations. Rate values are shown on curves at appropriate places.

The data show a high carry-over of 1969 standing dead material. This is readily explained by the fact that not all material was carried down by snow, rain, or wind to the litter biomass at the lightly grazed location. It should be noted that there was an exceptional amount of seedstalk production of fescue and Idaho fescue in 1969. Some of this material did not come down until midsummer or later. The amount of litter reflects limited use of both treatment areas for several years. Some comment should be made of the 1970 standing dead of the aboveground biomass. The change from standing live or green to standing dead came largely from forbs in late June and July as they dried more completely. The grasses such as native bluegrass and prairie June grass dried as entire plants, while the three major grasses started to dry from their lowermost leaves first. Idaho fescue had more leaves entirely dry early. Rough fescue had, in addition to some basal dry leaves, leaves drying from the tips well before entire leaves dried. Bluebunch wheatgrass had a complex drying process. The scattered seedstalks of the fescues dried early and more completely than did bluebunch wheatgrass. The process of decomposition of leaves in native bluegrass is completed quite early and contributes little to litter. See Fig. 9 and 10 for trend in total herbage production for 1970 and corresponding standard errors for the two treatments.

A comparison of the contribution of grasses and forbs as well as some species to net production under both treatments is of interest. If we refer to Tables 12, 13, 14, also Fig. 11 and 12, it will be apparent that rough fescue is a major component in the net production on the lightly used treatment, while the other grasses are quite

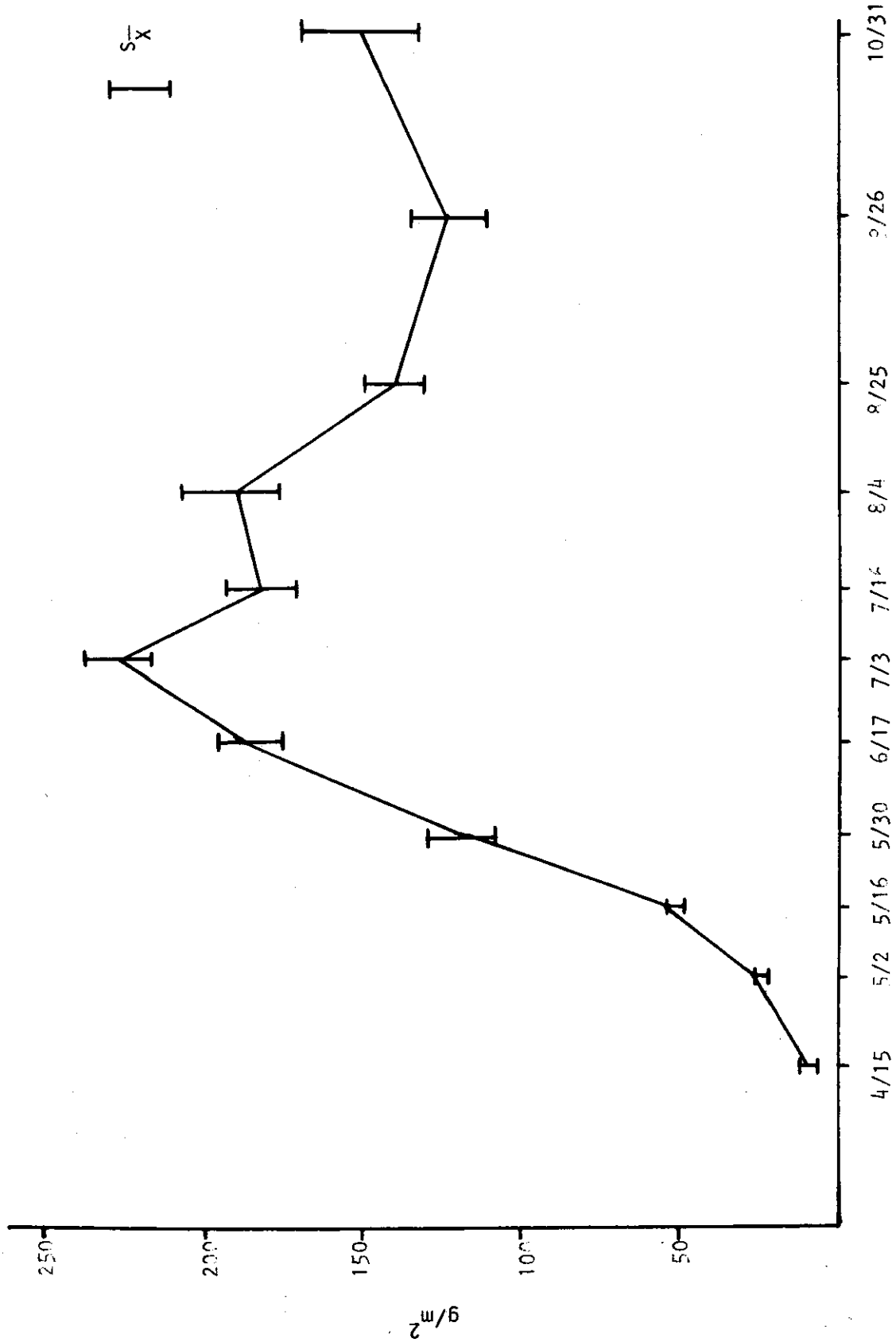

Fig. 9. Trend in total herbage produced in 1970 at various harvesting dates with corresponding standard errors for the location with the light to no grazing history.

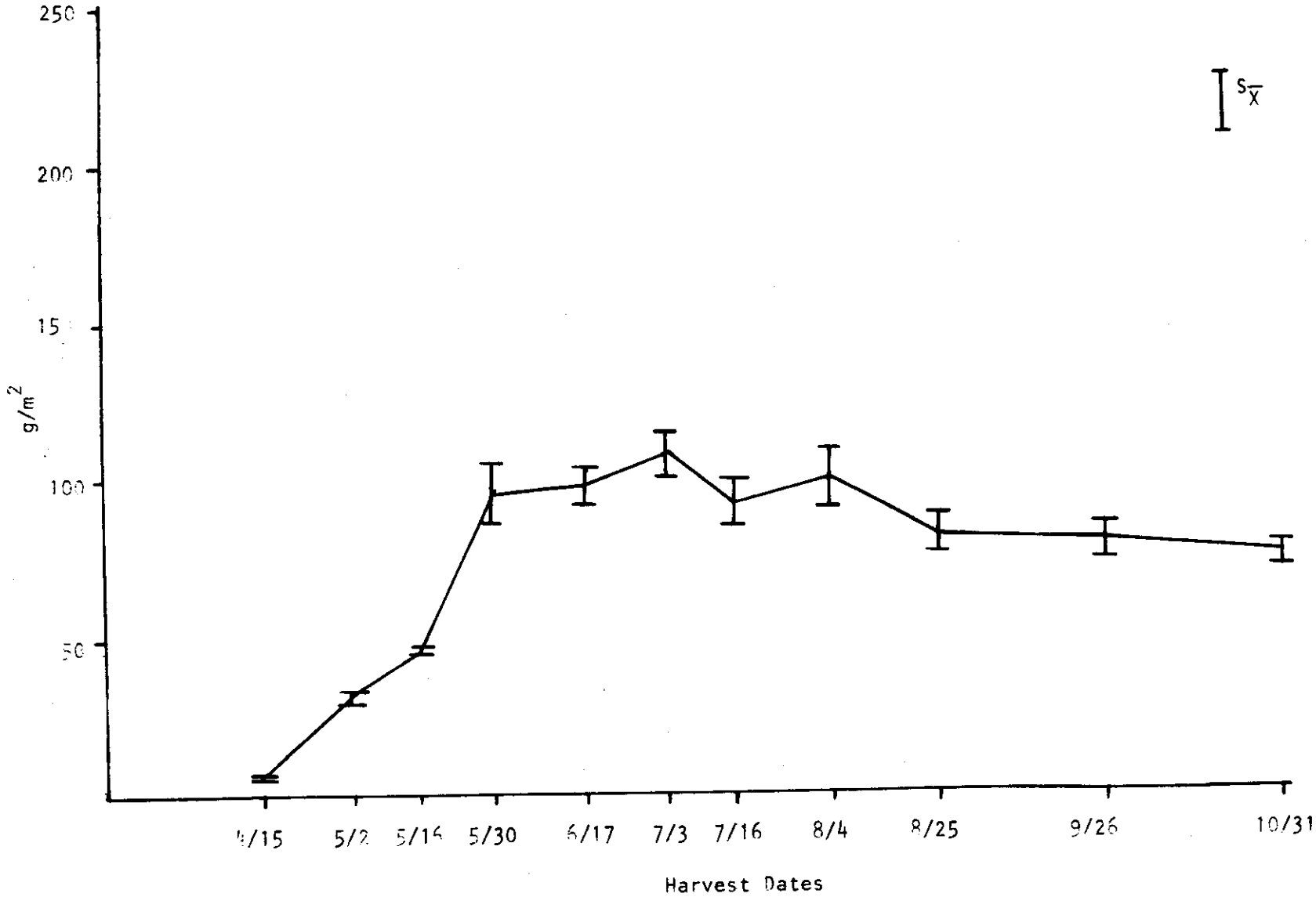

Fig. 10. Trend in total herbage produced in 1970 at various harvesting dates with corresponding standard errors for the location with the moderately close grazing history.

Table 13. Summary of the 1970 production of herbage including standing green and standing mature (dead) material at various harvesting dates through the growing season at the location with a history of light to no grazing. Data in g/m^2, oven-dry basis.

Species	4/15	5/2	5/16	5/30	6/17	7/3	7/16	8/4	8/25	9/26	10/31
	g/m^2										
Festuca scabrella	6.65	15.15	33.91	70.82	102.31	140.71	117.08	134.88	100.93	90.87	108.00
F. idahoensis	0.60	1.45	2.70	4.52	4.48	10.26	3.76	8.66	8.96	10.83	8.74
Agropyron spicatum	0.05		0.38	0.24	1.22	3.08	0.84	2.49	0.47	0.86	
Misc. perennial grass	0.06	0.33	0.40	0.84	1.72	1.73	2.74	1.49	0.45	1.63	0.58
Misc. annual grass				1.08	6.30	2.55	0.30	0.68	0.52		
TOTAL GRASS	7.36	16.93	37.39	77.50	116.03	158.33	124.72	148.20	111.33	104.19	117.32
Lupinus sericeus		0.01	3.67	15.66	41.30	34.26	27.36	16.63	11.46	9.83	14.12
Achillea millifolium		0.61	0.91	2.82	2.88	7.78	6.90	4.00	4.68	4.19	2.48
Lithospermum rudeale			0.43	5.14		4.32	8.46	9.59	3.83		
Geum triflorum		1.45	2.14	0.62	2.02	5.60	2.06	2.96			
Agoseris glauca		1.43	0.52	2.98	4.75	4.03	0.72	0.60	0.83		
Arnica fulgens		0.85	2.40	4.66	3.37	1.56	1.26	1.49	0.93		
Zigadenus paniculatus	0.35	0.30	0.13	0.28	0.06	0.47		0.03			
Castelleja sulphureus					0.93	1.82	0.42	1.64			
Misc. forbs	0.70	5.84	4.19	7.58	11.47	9.95	9.68	6.76	6.59	4.85	16.92
TOTAL FORBS	1.05	10.49	14.39	39.74	66.78	69.79	56.86	43.70	28.32	18.87	33.52
TOTAL	8.41	27.42	51.78	117.24	182.81	228.12	181.58	191.90	139.65	123.06	150.84

Table 14. Summary of the 1970 production of herbage including standing green and standing mature (dead) material at various harvesting dates through the growing season at the location with a history of moderately close to heavy grazing. Data in g/m^2, oven-dry basis.

Species	4/15	5/2	5/16	5/30	6/17	7/3	7/16	8/4	8/25	9/26	10/31
						g/m^2					
Festuca scabrella	0.16	0.58	0.17	1.38	3.72	3.29	10.18	4.71	3.24	3.95	4.04
F. idahoensis	2.76	8.89	14.72	16.41	18.42	25.85	14.92	28.62	32.35	19.67	24.78
Agropyron spicatum	1.16	4.66	7.34	15.03	18.42	26.25	28.16	28.54	25.35	19.36	21.40
Misc. perennial grass	1.48	3.09	6.01	9.60	8.94	6.23	8.74	9.46	1.86	20.88	5.98
Misc. annual grass		0.32	2.81	5.77	9.06	1.28	0.17	3.03	2.63	0.32	
TOTAL GRASS	5.56	17.54	31.05	48.19	58.56	62.90	62.17	74.36	65.43	64.18	56.20
Lupinus sericeus	0.04	1.26	0.94	19.32	11.06	20.72	9.94	8.09	2.70		0.92
Arnica fulgens		3.10	4.77	4.18	3.68	1.14	0.94		0.03		
Agoseris glauca	0.38	2.94	2.10	4.86	4.06	3.32	3.90	0.74	0.68		
Achillea millifolium	0.08	2.24	2.85	7.89	7.14	6.34	9.04	7.51	3.09	3.41	4.82
Zigadenus paniculatus	0.38	3.02	1.19	1.73	2.16	0.41		0.17	1.16		
Antennaria rosea		0.08	0.14	2.10		0.67		0.43	0.37		
Aster falcatus										5.22	4.12
Castelleja sulphurea		0.20		1.56	1.08	2.86	2.12	0.61			
Misc. forbs	0.54	1.68	3.74	6.19	10.53	9.82	8.50	10.21	9.46	9.49	11.76
TOTAL FORBS	1.42	14.52	15.73	47.83	39.71	45.28	34.44	27.76	17.49	18.12	21.62
TOTAL	6.98	32.06	46.78	96.02	98.27	108.18	96.61	102.12	82.92	82.30	77.82

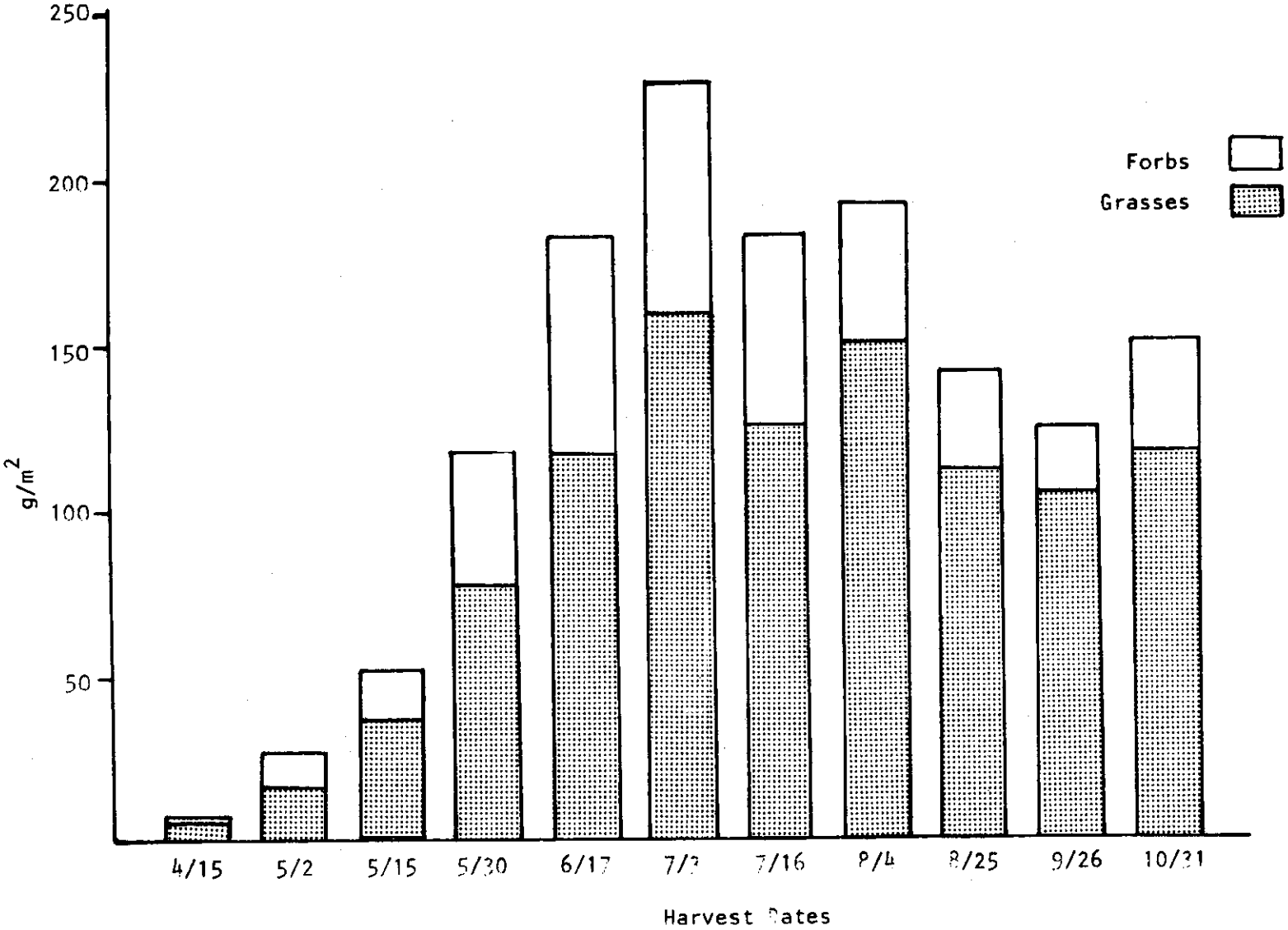

Fig. 11. Trend in herbage production by plant groups for 1970 at various harvest dates for the location with the light to no grazing history treatment.

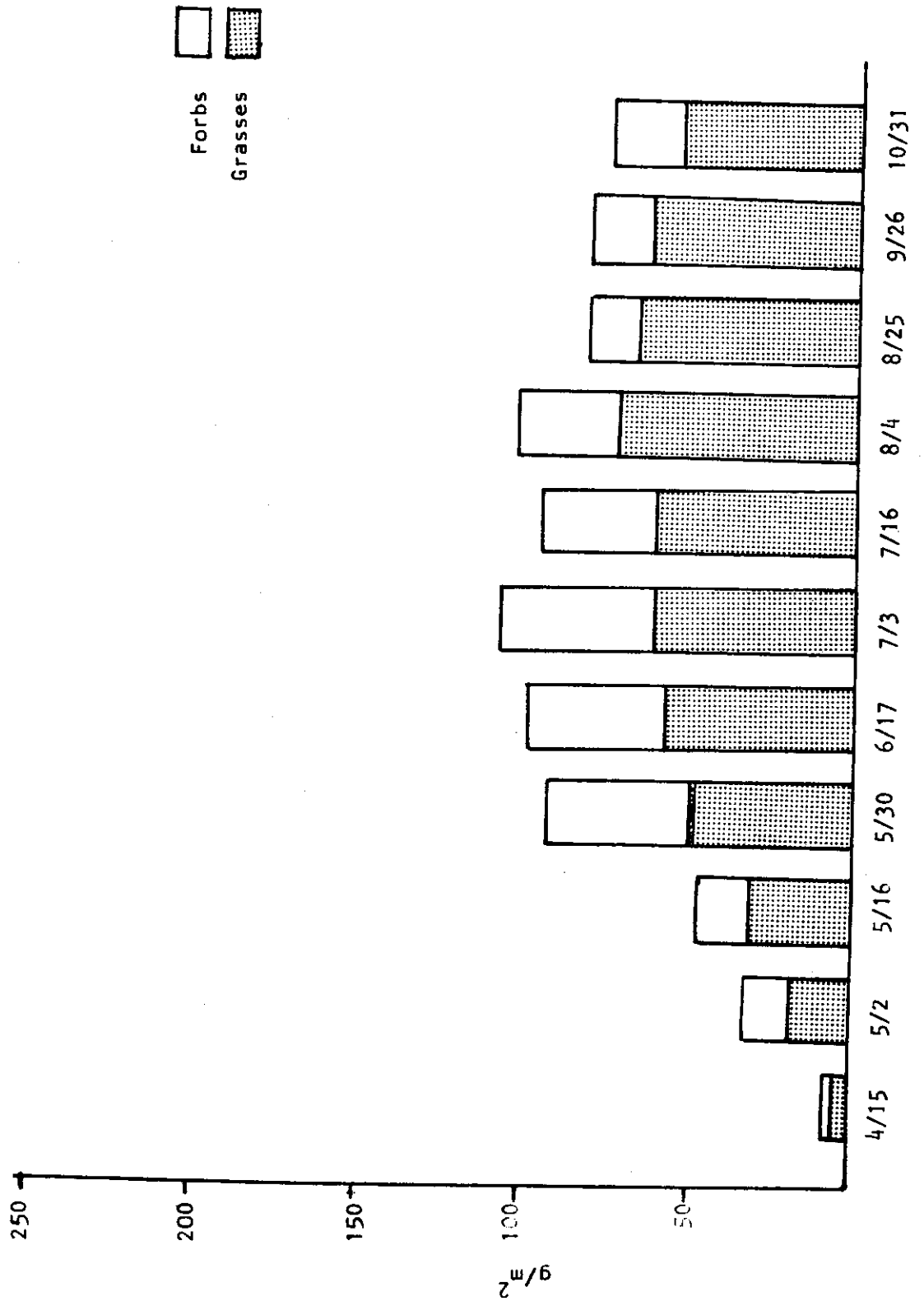

Fig. 12. Trend in herbage production by plant groups for 1970 at various harvesting dates for the location with the moderately close grazing history treatment.

secondary. Forbs are abundant under both treatments, and this is important to note for the lightly used treatment because it indicates that a significant amount of the energy, water, and mineral nutrients are available to them in spite of the dominant role of rough fescue. Lupine is especially abundant. To what extent it contributes to the nitrogen cycle in the total ecosystem is worthy of study. In general, the forbs vary more than the grasses in the time when they contribute to the total biomass.

The most significant aspect of the data on net production is the comparison of total net production for the two treatments. If the two areas are comparable on the basis of their abiotic characteristics, particularly moisture supply, then the seral stand, dominated by Idaho fescue and bluebunch wheatgrass, is about 40% as efficient as the vegetation dominated by rough fescue on the lightly used treatment in utilizing solar energy, water, and nutrients. This is essentially a measure of the grazing history of the two treatments and the genetic character of the species involved. As an additional bit of evidence that this relationship is not circumstantial or exceptional, data from a previous study in the Blackfoot Valley under slightly different environmental conditions but with a four-way comparison is presented in Appendix Table 10 and shows much the same thing.

Moss and Root Biomass

The separation of the aboveground and belowground biomass is not easily done in all ecosystems. In the nearly pristine Fescue Grasslands in western Montana true mosses and club moss (*Selaginella densa* Rudb.) present a problem in the same way. It is not clear what constitutes

living or dead material or what distinguishes above- from belowground material. At the Bison Site locations, a true moss (*Brachythecium albicans* (Hedw.) B., S. & G.) is common under the litter layer but is nearly absent from seral stages produced by heavy grazing use. This material was harvested only once during the season (July 17) because of the problems of separating the material from litter and surface soil.

The ash free value of this component is shown in Table 15. It is a contribution to total biomass and represents 3.3% of the total biomass. The portion of the 107 g which represents net productivity for 1970 would be difficult to provide. A rough estimate of 25 g is given in Table 15 under net primary productivity.

Several early attempts to obtain root data proved extremely difficult because of the rockiness of the soil. A single sample date and two sample sets at each location provide the working data. Each sample was 10 by 10 cm in cross-section and taken to the depths indicated in Table 16.

The data on roots is essentially the fibrous roots of tufted bunchgrasses. A few of the forbs may be rhizomatous and, if they appeared in the sample, were included in the root data. The root distribution patterns reflect the difference in the abundance of the dominant grasses at the two locations. For the lightly grazed treatment, 88% of the root weights is in the first 30 cm. For the moderately close grazed treatment, approximately 92% of the root weight is in the first 20 cm. The total root weights corresponding to the two treatments are 2540 g/m^2 and 1470 g/m^2, respectively. The amount of root material from the closely grazed treatment is 58% of the

Table 15. Analysis of plant biomass and net primary production for 1970 at the Bison Site for two levels of past grazing intensity by large herbivores.

Component	Grazing History			
	Light to None		Moderately Close	
	g/m^2	%	g/m^2	%
Maximum Biomass				
Standing Live	253	8.03	149	8.62
Standing Dead (1969)	140	4.44	67	3.87
Litter	180	5.71	42	2.43
Moss	107	3.39	Trace	—
Roots	2470	78.41	1470	85.06
TOTAL	3150	99.98	1728	99.98
Net Primary Productivity				
Standing Live				
Grasses	163	30.69	90	30.20
Forbs	90	16.94	59	19.79
Moss (green)	25	4.70	—	—
Roots	253	47.64	149	50.00
TOTAL	531	99.97	298	99.99

Table 16. Distribution of root material under light and moderately close grazing conditions. Oven-dry weights, August 18, 1970.

Soil Depth (cm)	Light Grazing Use		Moderately Close Grazing	
	g/m^2	Percent of Total Wt.	g/m^2	Percent of Total Wt.
0- 5	1070	42.12	950	64.62
5-10	650	25.59	240	16.32
10-20	340	13.38	160	10.88
20-30	170	6.69	30	2.04
30-40	140	5.51	30	2.04
40-50	40	1.57	40	2.72
50-60	60	2.36	20	1.36
60-70	70	2.75	-	no data
TOTAL	2540	99.98	1470	99.98

lightly grazed treatment and is in almost exact correspondence with the relationship of the aboveground standing live herbage as presented in Table 15. The data for the lightly grazed treatment compare well with the results obtained under a rough fescue stand in Saskatchewan (Coupland and Brayshaw 1953). The percent of root material in the first 30 cm is comparable. The Saskatchewan results show 85.4%, and for this location it is 88%. Comparison with the results of Weaver and Darland (1949) for big bluestem (*Andropogon gerardi* Vitm.), and little bluestem (*Andropogon scoparius* Michx.), indicate that the total root production here is much higher for big bluestem and only slightly higher for little bluestem.

Maximum Plant Biomass

Total biomass is perhaps one of the very important elements in characterizing ecosystems. Comparisons can be made between a wide variety of ecosystems. Nevertheless, there are some limitations in such information. Nonliving components can be quite transitory as well as difficult to compare from one ecosystem to another. Data in Table 15 is calculated from the sum of each species' maximum production values (Kelly, Van Dyne, and Harris 1970).

Total plant biomass of 3150 g/m^2 from the lightly grazed locations is probably average for subhumid grasslands. It is less than the values reported by Kucera, Dahlman, and Koeling (1967). The most striking figure is the amount of belowground biomass and its relation to aboveground biomass. Of the total biomass, 62% is below ground.

Net Primary Production

This characteristic of an ecosystem is a more straightforward feature of ecosystem function and is less confounded than biomass data. However, in our analysis, it was necessary to make an estimate of gross moss weight and of gross root weight that represents one year of net production. In regard to the moss, it was estimated that about one-fourth was green and represents this season's growth. Kucera et al. (1967) use a value of 50% of total net primary productivity as equivalent to approximately the annual growth of the roots. Data reviewed by Troughton (1957) are mainly below this figure. The net primary production for aboveground herbage is not out of line with values obtained elsewhere (Weaver and Darland 1949, Larson and Whitman 1942, Van Dyne, Vogel, and Fisser 1963, Pearson 1965). The calculated value of 531 g/m^2/year is in line with Whittaker's (1970) figure for temperate grassland of 500 g if he includes belowground net primary production.

A comparison of the two treatments, in terms of net primary productivity, is of interest. The comparative distribution of similar components is striking. While it was expected that there would be a higher proportion of the forbs in the moderately close grazed treatment, it is not exceptionally so.

The conversion of biomass and net primary productivity values to energy units in order to analyze the functioning of the ecosystems can lead to some useful information. However, to determine efficiency of an ecosystem on the basis of percent of radiant energy used on a calorie basis leaves much to be desired. Applications of energy flow through various trophic levels is certainly the best use.

Comparison of energy equivalents of biomass between ecosystems is a convenience when comparisons are made over a considerable distance. Golley (1961) provides some data from which one can use a value of 4200 cal per gram of dry matter. If this is used, we have then a net primary productivity value in energy equivalent of 2230 kcal and 1252 kcal per square meter for the two treatments, light and moderately close, respectively.

SUMMARY

Seasonal change in plant biomass components were determined for 1970 at the National Bison Range northwest of Missoula, Montana.

Two treatments were involved. One had a grazing history of light to no use. The other had a history of moderately close grazing. Neither treatment area was grazed during the 1970 growing season.

Trends in 1970 standing green growth, 1970 standing dead (mature herbage), 1969 standing dead, and 1970 litter were assessed by harvesting biweekly or monthly between mid-April and the end of October. A single collection provided an estimate of moss biomass. Net primary production was estimated by summing the biomass of each species at the peak of its production. Current moss production was estimated to be 25% of gross production. Root production was estimated to equal aboveground production, exclusive of moss biomass.

Weather records on site at the Bison Range headquarters as well as other locations in the grassland habitat type provide background data. The 1970 climatic year is defined as extending from September 1 of the previous year to August 31 of the next year. In general, precipitation and temperature conditions were favorable.

Plant growth of the principal grasses and many forbs starts in the fall after some 2 to 3 cm of precipitation has occurred. Flowering and fruiting of the dominant grass species (rough fescue, Idaho fescue, bluebunch wheatgrass, and balsamroot) were near failures in 1970. The lack of flower stalk development is common in most years and appears to be linked to the moisture supply in September of the previous year.

Leaf growth and production were average or better. Rough fescue was 17 cm high on April 15. This was some 35% of the final growth. On the same date herbage production (total) was 24% of the peak production. Most species had completed growth by July 3. In some 80 days between April 15 and July 3, 96% of the production takes place.

Temperatures above 5°C initiate rapid growth, and growth is completed when temperatures are still below 30°C. Cessation of height growth takes place before that of weight production. Soil moisture is the second major physical factor of the environment's control of growth. Growth is terminated when moisture stress of -15 bars is reached. This occurred about July 3 in 1970. Herbage moisture content was equal to 100% of the oven dry-weight of the herbage at that time.

Standing dead material from the previous year was not incorporated into the litter layer until after midsummer. Standing dead herbage produced in 1970 remained as such through the summer. Early forbs and native bluegrass matured early and became part of the litter layer before midsummer or else decomposed in place.

Total aboveground biomass was calculated from peak production dates by species. The lightly grazed treatment biomass components were standing live 8%, 1969 standing dead 4%, litter 6%, moss 4%, belowground (roots) 78%, for a total of 3170 g/m^2. The moderately

close grazing treatment had a lower percentage of litter when compared to the other treatment but a higher percentage of roots. However, the total plant biomass was only 1728 g/m^2 or 55% of the lightly grazed treatment.

The lightly grazed treatment produced 531 g/m^2, and the moderately close treatment produced 298 g/m^2. This was 56% of the lightly grazed treatment. The contribution of moss to the net productivity is of interest from a soil management standpoint. The estimate of root production as net primary production in comparison to root biomass has implications regarding turnover rates for belowground and aboveground biomass, i.e., either the belowground turnover is slower, or roots have considerable longevity.

A comparison of net primary productivity between the two treatments better reflects poor utilization of precipitation than use of radiant energy.

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APPENDIX I

APPENDIX TABLES

Appendix Table 1. Monthly precipitation reported from four localities in western Montana Source, U.S. Department of Commerce, Environmental Services Administration, Montana,1969. Data in mm. Distance from National Bison Range headquarters in kilometers.

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
						Missoula (53 km SE)							
1968-69	48.77	13.72	13.97	29.72	74.68	13.21	18.29	16.25	30.73	106.17	6.35	1.02	372.88
1969-70	16.76	17.02	10.67	23.37	72.89	8.36	26.92	27.18	44.45	72.14	42.67	2.03	364.46
Lt. Avg	26.92	24.38	23.62	28.45	22.61	18.79	16.51	24.38	46.23	50.55	23.11	19.05	324.60
						Lonepine (Includes Hot Springs) (46 km NW)							
1968-69	53.34	26.42	15.49	36.83	71.63	8.13	15.75	25.15	6.10	73.15			
1969-70					77.98	12.19	36.32	46.23	26.42	49.02	62.74	3.05	
Lt. Avg	22.35	26.92	30.48	27.43	26.16	20.83	17.78	18.29	28.45	41.15	15.49	15.75	291.08
						Polson (47 km N)							
1968-69	57.91	28.95	30.73	34.29	56.39	7.11	21.84	26.42	26.16	104.65	17.02	.00	411.47
1969-70	27.43	26.67	1.02	24.89	58.67	27.69	36.58	18.79	64.01	50.80	78.74	28.70	443.99
Lt. Avg.	31.24	32.77	29.72	29.46	25.91	24.64	22.61	29.46	49.02	57.66	25.40	23.88	381.77
						St. Ignatius (15 km E)							
1968-69	112.77	26.92	19.30	28.95	60.19	6.35	19.05	22.86	48.51	127.76	11.43	00.51	484.60
1969-70	18.29	39.12	5.84	24.89	46.48	15.49	45.46	62.48	87.38	81.03	70.61	16.76	513.38
Lt. Avg	31.75	30.48	25.65	22.86	21.34	21.59	25.15	33.53	56.13	63.75	24.89	26.42	383.55

Appendix Table 2. Mean monthly temperatures in °C for four localities in western Montana.

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
						Missoula						
1968-69	12.6	5.6	0.9	-5.7	-7.8	-6.3	-1.7	8.1	12.4	14.9	17.9	19.4
1969-70	13.8	4.5	-0.1	-3.3	-5.1	0.1	1.2	4.3	11.4	17.2	20.1	19.8
Lt. Avg	14.1	7.8	0.7	-2.9	-5.3	-2.5	2.2	8.0	12.6	15.8	20.3	19.1
						Lonepine (Including Hot Springs)						
1968-69	12.8	6.3	1.3	-6.5	-10.7	-5.9	-3.1	8.8	13.2	16.1		
1969-70	14.1	5.3	1.7	-2.1	-3.9	0.7	0.8	4.8	12.2	17.8	20.3	19.1
Lt. Avg	14.1	8.0	0.5	-2.3	-5.1	-3.2	1.5	7.6	12.3	15.7	20.1	18.8
						Polson						
1968-69	12.7	6.4	1.4	-5.5	-8.7	-4.4	-1.6	7.7	11.6	14.9	18.1	18.9
1969-70	14.1	5.5	1.9	-1.9	-3.9	-0.4	0.9	4.7	11.6	16.9	19.8	18.9
Lt. Avg	13.8	7.9	1.4	-1.3	-3.8	-2.4	1.7	7.2	11.7	15.4	19.6	18.7
						St. Ignatius						
1968-69	13.2	6.8	2.2	-5.1	-8.5	-4.5	-1.1	8.8	13.1	15.6	18.3	18.9
1969-70	14.1	5.5	1.6	-1.7	-3.7	0.2	1.6	4.8	12.4	18.0	20.5	19.4
Lt. Avg	14.0	8.3	1.5	-1.3	-3.8	-2.0	2.3	7.9	12.4	15.7	19.8	18.7

Appendix Table 3. Weekly precipitation totals for the National Bison Range headquarters and the two treatment locations through the main growing season for 1970 and four year average.

Period	Location and Year			
	Headquarters		Light	Mod. Close
	1967-70 Avg	1970	1970	1970
	mm			
4/15 - 4/25	10.26	9.49	8.97	9.49
4/26 - 5/3	12.05	5.38	3.57	2.82
5/4 - 5/10	9.74	13.33	18.72	17.18
5/11 - 5/17	13.59	36.67	22.05	37.95
5/18 - 5/22	5.38	6.41	4.87	5.38
5/23 - 5/30	8.21	2.05	0.00	0.00
6/1 - 6/5	5.64	1.03	17.95	0.77
6/6 - 6/12	32.05	22.82	25.38	17.95
6/13 - 6/19	4.10	9.23	11.79	11.79
6/20 - 6/25	21.03	0.00	0.00	0.00
6/26 - 7/3	14.62	21.03[a]	13.59	16.41
7/4 - 7/10	0.07	0.00	0.00	0.00
7/11 - 7/16	5.13	19.74[b]	0.00	13.33
7/17 - 7/23	4.62	17.18[c]	0.00	4.36
7/24 - 7/30	6.41	25.89[d]	14.10	17.69
7/31 - 8/6	1.79	5.89	4.62	3.33
8/7 - 8/13	1.03	0.00	0.00	0.00
8/14 - 8/18	10.00	0.00	0.00	0.00
8/19 - 8/25	0.51	0.00	0.00	0.00
8/26 - 8/27	1.54	0.00	0.00	0.00
8/28 - 9/3	7.44	0.00	0.51	0.77
9/4 - 9/10	5.38	16.41[e]	14.87	11.79
9/11 - 9/17	6.67	1.54	0.00	0.00
9/18 - 9/24	9.74	3.08	4.62	6.92
9/25 - 10/1	3.08	0.00	0.00	0.26
10/2 - 10/16	20.26	37.44	37.44	37.44
10/17 - 10/31	10.00	2.56	2.05	3.58
TOTAL	226.67	257.18	205.13	219.23

[a] Two days; 14.48,6.35.
[b] Three days; 1.78, 16.51, 1.27.
[c] One day.
[d] Four days; 2.27, 7.11, 5.08, 11.18; last three consecutively.
[e] One day.

Appendix Table 4. Daily mean temperature in °C at 1 m. Lightly grazed location, 1970.

Date	April	May	June	July	August	September	October
1		11.1	18.9	19.4	16.1	19.4	15.5
2		15.5	23.3	20.0	13.9	17.2	12.8
3		25.5	25.5	23.9	13.3	17.8	13.3
4		18.3	25.5	23.9	17.2	10.5	17.8
5		21.7	25.0	25.0	18.9	11.1	10.0
6		17.8	22.8	22.8	21.1	13.3	0.0
7		10.0	19.4	22.8	21.7	13.3	0.6
8		12.2	19.4	23.9	16.7	10.5	1.7
9	9.4	12.2	15.0	26.1	17.2	9.4	2.8
10	8.3	7.8	12.2	21.7	18.9	11.7	5.6
11	3.9	6.7	12.8	20.5	20.5	6.1	
12	3.3	7.2	11.1	18.3	24.4	2.8	
13	3.3	8.3	11.1	11.1	21.7	2.8	
14	3.3	12.2	12.2	14.4	18.3	4.4	
15	2.8	17.2	12.2	21.1	20.5	7.8	
16	5.0	21.1	11.7	21.7	21.1	8.3	
17	7.2	21.7	15.0	18.9	18.9	11.7	5.0
18	7.2	15.5	20.0	18.9	17.2	12.8	6.1
19	5.6	17.8	20.0	21.1	17.2	10.0	8.3
20	2.8		22.8	23.9	19.4	8.3	7.2
21	2.8		23.3	20.0	22.8	8.9	6.7
22	3.9		25.5	13.9	23.9	10.0	5.6
23	6.1	17.8	24.4	16.1	24.4	7.2	4.4
24	5.6	18.9	26.1	18.9	25.0	5.0	1.7
25	4.4	21.2	25.0	13.3	26.1	6.7	-1.1
26	1.1	21.7	25.0	16.1	21.1	8.3	-1.1
27	2.2	15.0	19.4	17.7	20.5	10.0	-1.1
28	3.9	14.4	15.5	13.9	20.5	11.7	-1.7
29	4.4	12.2	8.9	14.4	18.9	12.8	-0.6
30	5.6	12.2	8.9	13.3	17.8	13.3	-0.6
31		15.5	14.4	13.9	21.1		-1.1
MEAN		15.3	18.5	19.4	19.9	10.1	4.8

Appendix Table 5. Daily mean temperature in °C at 1 m. Moderately close grazing location, 1970.

Date	April	May	June	July	August	September	October
1		8.9	13.9	7.8	13.9	18.9	14.4
2		12.2	17.8	11.7	12.2	17.2	12.8
3		15.5	19.4	18.3	11.7	16.1	12.8
4		14.4	20.5	21.1	14.4	9.4	
5		17.2	19.4	22.8	15.5	11.7	10.0
6		13.9	18.9	20.0	20.0	13.3	0.6
7		7.2	15.5	20.0	22.8	13.9	1.7
8		8.9	15.0	21.1	16.7	10.0	2.8
9		8.3	11.1	22.8	16.1	10.0	
10		5.0	9.4	17.8	17.8	12.2	5.0
11		2.2	10.0	18.3	19.4	6.1	8.3
12		3.9	9.4	16.1	21.7	2.8	8.3
13		4.4	10.0	10.0	21.1	3.3	7.2
14		7.8	10.5	12.8	19.4	3.9	3.3
15		11.7	10.5	16.7	18.9	6.7	2.8
16		16.1	10.0	19.4	22.2	7.8	5.0
17		17.2	13.3	17.2	20.5	12.8	3.3
18		11.7	17.2	17.2	18.3	12.2	2.2
19		13.3	21.1	19.4	18.3	10.5	7.2
20	1.1	10.0	20.0	21.1	19.4	8.9	6.7
21	1.7	11.7	21.1	18.9	21.1	8.9	5.6
22	2.8	12.2	22.2	12.8	22.2	10.5	5.6
23	4.4	13.3	23.3	13.3	22.2	8.3	6.1
24	4.4	14.4	23.3	15.5	23.9	5.6	4.4
25	2.8	16.1	15.5	11.1	26.7	6.1	1.1
26	2.2	16.7	23.3	14.4	20.5	9.4	0.0
27	1.1	10.5	20.0	13.9	19.4	10.0	1.1
28	2.8	10.0	16.7	11.7	20.0	11.7	0.0
29	3.3	8.3	12.8	12.8	17.8	12.8	0.0
30	5.5	8.9	6.7	11.7	17.2	14.4	0.0
31		11.7		12.2	19.4		-0.6
MEAN	4.4	11.1	16.1	16.1	19.2	10.0	4.7

Appendix Table 6. Mean daily temperature in °C at a soil depth of 25 cm. Lightly grazed location, 1970.

Date	April	May	June	July	August	September	October
1				11.1	13.6	15.2	
2				13.9	13.7	14.5	6.6
3				15.7	12.8	14.8	6.4
4				15.3	13.9	11.2	7.8
5				15.9	15.5	10.4	6.4
6				17.0	15.8	10.6	4.1
7				16.4	17.5	11.3	3.5
8				16.5	16.0	10.7	1.6
9				18.0	14.1	8.8	
10				18.2	14.5	9.9	
11				16.4	15.3	7.4	
12				15.2	16.5	5.3	
13			10.5	12.3	16.9	4.5	
14		8.4	10.8	12.1	13.7	3.9	
15		8.3	10.2	13.5	13.0	4.6	
16		8.7	10.0	15.2	13.8	4.7	
17		8.1	10.4	14.8	13.3	5.9	-1.1
18		8.5	11.5	14.8	12.5	4.3	-1.0
19		6.7	11.4	16.0	14.2	3.5	0.6
20		5.5	10.9	17.4	14.8	2.8	1.1
21		4.9	11.5	17.3	15.2	2.3	1.1
22		5.5	13.0	15.1	15.4	2.4	1.4
23		9.5	13.5	15.2	16.0	2.5	2.1
24		10.5	14.2	16.3	16.8	2.4	1.7
25		11.1	14.7	14.9	18.9	3.1	1.5
26		12.5	15.5	14.3	17.5	3.5	
27		11.5	15.4	15.7	16.7	4.1	
28			13.5	14.4	15.9	4.6	
29			13.2	14.7	15.2	5.2	
30			11.5	13.7	14.8	5.9	
31				12.8	15.5		
MEAN		8.6	12.3	15.1	15.1	6.7	2.7

Appendix Table 6a. Mean temperatures in °C for ungrazed and grazed treatments for the 1970 growing season. Based on harvest periods. Supplement to Table 6.

Position (cm)	Dates										
	4/15	4/16 5/2	5/3 5/16	5/17 5/30	5/31 6/17	6/18 7/3	7/4 7/16	7/17 8/4	8/5 8/25	8/26 9/26	9/27 10/31
	Ungrazed Treatment										
Air											
100.0[a]	--	5.6	13.9	17.2	17.2	20.0	21.1	16.7	20.5	12.8	5.7
2.5[a]	--	--	13.9	12.9	12.1	21.2	26.2	17.4	19.4	5.9	-0.8
2.5[b]	--	--	13.5	8.4	9.4	21.1	12.5	11.5	8.5	-1.1	-0.2
Soil											
2.5[a]	--	--	12.3	9.3	11.9	15.0	17.4	18.4	22.1	9.8	4.1
25.0[a]	--	(7.5)	8.6	8.6	10.3	13.2	15.5	14.8	15.0	8.6	2.7
2.5[b]	6.9	8.6	9.8	6.9	5.0	12.1	14.0	13.7	13.9	7.9	3.8
25.0[b]	6.1	7.2	8.0	8.4	10.4	12.7	15.1	13.6	14.0	8.0	2.7
75.0[b]	--	6.8	7.3	8.8	10.6	11.1	12.6	13.4	13.8	11.9	9.8
	Grazed Treatment										
Air											
100.0[a]	--	4.1	9.7	12.6	13.7	17.5	17.9	14.4	19.9	12.0	4.8
2.5[b]	10.5	13.3	16.8	31.3	28.4	25.5	20.4	23.9	20.2	13.1	13.3
Soil											
2.5[b]	8.9	11.8	15.3	15.6	15.2	12.8	16.2	13.4	13.9	8.6	3.3
25.0[b]	6.1	8.7	12.2	11.9	13.1	13.9	17.5	14.9	16.2	10.9	5.6
75.0[b]	6.7	6.4	6.8	8.7	11.4	11.7	14.9	14.7	14.9	12.9	9.1

[a] Temperatures are an average of two hour readings recorded on a continuously recording thermograph.

[b] Temperatures are an average of weekly readings made by thermocouple at 9:00 AM Mountain Standard Time.

Appendix Table 7. Daily mean relative humidity in shelter at 1 m. Lightly grazed location, 1970.

Date	April	May	June	July	August	September	October
1			57.3	64.0	53.5	59.5	
2			59.8	69.9	78.5	50.1	
3			58.5	63.8	70.8	53.4	
4		48.3	59.1	62.2	66.5	94.7	
5		45.1	64.0	44.5	71.9	70.2	
6		74.0	76.6	38.4	69.8	63.5	
7		91.0	78.2	40.5	53.2	77.8	
8		76.4	73.8	43.6	51.0	74.5	
9		73.7	79.9	40.0	48.8	63.8	
10		84.2	67.7	63.4	51.2	54.7	
11		84.3	70.9	67.7	48.9	78.0	
12		88.8	87.2	72.2	43.5	64.9	
13		81.8	90.0	92.8	45.7	58.4	
14		56.1	89.8	65.8	42.5	57.8	
15		47.4	87.2	51.8	50.8	48.6	
16		51.1	93.9	63.7	42.6	59.2	
17		44.5	84.2	63.9	29.7	62.2	
18		57.6	67.5	54.3	30.6	73.7	
19			44.2	54.8	42.8	84.1	
20			53.4	47.6	45.6	80.3	
21			62.0	56.5	39.0	80.2	
22			52.5	55.5	38.0	77.5	
23		60.6	51.4	55.9	34.0	67.5	
24		53.4	45.2	47.8	36.2	63.8	
25		56.5	60.6	77.1	30.5	55.8	
26		45.2	39.2	76.5	33.8	74.3	
27		58.0	50.4	83.6	38.5	76.2	
28		60.1	84.8	84.9	39.2	74.0	
29		82.5	66.5	58.7	50.2	67.8	
30		84.7	85.3	50.2	62.2	50.0	
31		68.0		58.2	64.7		
MEAN		65.6	68.0	60.3	48.5	67.2	

Appendix Table 8. Daily mean relative humidity in shelter at 1 m. Moderately close grazing location, 1970.

Date	April	May	June	July	August	September	October
1			58.2	64.9	64.1	66.0	66.8
2			59.6	61.4	88.8	60.1	85.7
3			61.1	61.4	76.2	78.0	87.1
4		42.8	64.2	64.2	66.9	98.0	54.8
5		39.3	67.2	44.9	82.5	78.2	87.5
6		65.8	76.7	38.3	67.7	79.0	97.3
7		86.0	80.2	40.0	56.9	87.9	85.5
8		71.1	81.0	46.1	50.8	83.8	91.9
9		79.0	70.5	44.2	54.8	73.6	97.9
10		85.0	60.8	73.1	52.5	65.2	87.1
11		82.0	68.2	69.2	52.7	96.1	86.3
12		88.8	86.9	76.8	43.5	73.3	82.6
13		84.0	88.3	94.2	41.5	56.7	60.0
14		64.6	86.5	64.1	49.5	69.3	85.1
15		50.1	91.9	55.7	58.8	65.5	91.8
16		54.9	96.6	65.4	49.2	79.3	95.3
17		41.0	77.3	60.9	30.9	80.6	97.1
18		60.3	62.6	48.2	33.7	92.8	97.1
19		78.8	40.9	52.3	44.2	90.9	95.8
20		96.3	54.0	48.0	50.2	91.4	93.5
21		78.6	60.8	52.5	41.4	89.7	75.8
22		81.7	51.8	60.8	42.2	94.0	93.0
23		61.6	46.6	62.8	41.4	78.3	88.2
24		53.3	38.7	51.8	41.8	78.8	85.3
25		56.9	32.6	80.0	34.8	73.6	87.5
26		42.0	51.4	78.9	41.6	81.6	85.8
27		56.5	85.6	84.3	51.5	88.1	80.0
28		57.6	62.5	80.2	51.5	85.5	92.9
29			83.0	56.6	65.0	87.8	98.4
30		88.9	56.3	56.0	81.8	63.0	96.0
31		64.5		60.8	82.5		97.8
MEAN		67.1	66.8	59.2	54.9	79.5	87.3

Appendix Table 9. Wind speed record for the lightly grazed location based on accumulated readings for period and reduced to mph and m/sec for 1970.

Date and Hour Read	Accum. Anemometer Reading	Diff. in Miles	Diff. in Hours	Average	
				mph	m/sec
May 2-1200	959.1				
May 22-1500	954.0	1094.9	483	2.26	1.010
May 29-1200	306.7	352.7	165	2.14	.956
June 12-1600	949.6	642.9	340	1.89	.845
June 25-0900	403.0	453.4	305	1.49	.660
July 3-1300	739.8	336.8	196	1.72	.769
July 10-1200	127.0	387.2	167	2.32	1.037
July 16-1400	442.8	315.8	148	2.13	.952
July 23-1200	793.2	350.4	166	2.11	.943
Aug. 6-1600	549.1	755.9	340	2.22	.992
Aug. 18-1600	327.7	778.6	288	2.70	1.207
Aug. 24-1800	639.1	301.4	146	2.06	.921
Sept. 3-1500	225.9	586.8	237	2.48	1.108
Sept. 10-1400	640.9	415.0	167	2.49	1.113
Sept. 17-1500	139.9	499.0	169	2.95	1.319
Sept. 24-1500	617.4	477.5	168	2.84	1.269
Oct. 1-1500	966.7	349.3	168	2.07	.925
Oct. 16-1600	692.9	726.2	361	2.01	.898
Oct. 22-1500	981.2	288.3	143	2.01	.898
Oct. 29-1500	349.0	367.8	166	2.22	.992

Appendix Table 10. Herbage production under two site conditions and two levels of past grazing use at Blanchard Flat, August 1968[a/].

Species	Rough Fescue Site Swale		Idaho Fescue Site Flat Terrace	
	Protected	Grazed	Protected	Grazed
	g/10 sq ft			
Festuca scabrella	58.14	8.00	1.20	.07
Festuca idahoensis	11.84	23.69	21.10	17.30
Danthonia unisp.	.52	1.59	.10	.01
Carex filifolia	6.94	4.62	7.02	7.20
Misc. grasses	3.62	7.07	4.38	12.30
Forbs	16.16	9.01	13.94	4.40
TOTAL	97.22	53.98	46.58	41.30

a/ Based on average of ten 1 ft by 10 ft plots. Weights are air-dry weights.

Study location involves two areas divided by a fence. The protected area had not been grazed since 1947. The grazed area had moderately heavy cattle and horse grazing from 1960 to 1966 and then more or less ungrazed. The swale and terrace extends through both pastures. The swale type is a deep, fine sandy loam, and the terrace is a shallow gravelly loam. Rough fescue is considered climax dominant on the fine sandy loam and Idaho fescue the climax dominant on the coarse soil. The differences in yields are striking.

APPENDIX II

FIELD DATA

Aboveground Biomass Data

Aboveground biomass data collected in 1970 at the Bison Site is Grassland Biome Data Set A2U0002. Data were collected on Form NREL-01. A copy of the form and an example of the data are attached.

IBP

GRASSLAND [illegible]

FIELD DATA SHEET - ABOVE [illegible] BIOMASS

DATA TYPE	SITE	INITIALS	DATE			TREATMENT	REPLICATE	PLOT SIZE	QUADRAT	CLIP RANK	GROWTH FM.	GENUS	[illegible]	[illegible]	[illegible]	PANS	SACK NO.	DRY WT.	SPECIAL	DRY WT. SP.
			Day	Mo	Yr															
1-2	3-4	5-7	8-9	10-11	12-13	14	15	[illegible]	21-23	25	27	29-[illegible]	[illegible]	[illegible]	[illegible]	39-40	41-[illegible]	47-52	54-57	59-64

DATA TYPE
01 Aboveground Biomass
02 Litter
03 Belowground Biomass
10 Vertebrate - Live Trapping
11 Vertebrate - Snap Trapping
12 Vertebrate - Collection
20 Avian Flush Census
21 Avian Road Count
22 Avian Road Count Summary
23 Avian Collection - Internal
24 Avian Collection - External
25 Avian Collection - Plumage
30 Invertebrate
40 Microbiology - Decomposition
41 Microbiology - Nitrogen
42 Microbiology - Biomass
43 Microbiology - Root Decomposition
44 Microbiology - Respiration

SITE
01 Ale
02 Bison
03 Bridger
04 Cottonwood
05 Dickinson
06 Hays
07 Hopland
08 Jornada
09 Osage
10 Pantex
11 Pawnee

TREATMENT
1 Ungrazed
2 Lightly grazed
3 Moderately grazed
4 Heavily grazed
5 Grazed 1969, ungrazed 1970
6
7
8
9

PHENOLOGY
01 Germinated or sprouted
02 Early vegetation
03 Prebud
04 Bud stage
05 Early bloom
06 Mid-bloom
07 Full bloom
08 Late bloom
09 Milk stage
10 Dough stage
11 Ripe seed
12 Past ripe
13 Stem cured
14 Vegetative regrowth
15 Regrowth flowering
16 Regrowth ripe seed
17 Standing dead
18 Winter dormant

CLIP RANK
1 Harvested
2 Harvested and ranked
3 Ranked

GROWTH FORM
1 Perennial grass
2 Annual grass
3 Sedge, rush, etc.
4 Annual forb
5 Biennial forb
6 Perennial forb
7 Half-shrub
8 Shrub
9 Tree
0 Miscellaneous

+++ EXAMPLE OF DATA +++

```
         1         2         3         4         5
12345678901234567890123456789012345678901234567890123456789

0109DBA160770110.50
                  1  2  1 ANSC    03  1  200   48.82
                  1  2  1 SONU    03  2  201    9.80
                  1  2  1 ANSC    17  3  203   42.81
                  1  2  6 FORB A  03  4  204    0.14
                  1  2  1 MISC B  12  5  205    0.01
                  1  2  3 SEDG A  03  6  250    0.44
                  1  2  1 SPAS    03  7  247    0.54
                  2  2  1 ANSC    03  2  208   19.44
                  2  2  1 ANSC    17  3  209   98.04
                  2  2  1 SPAS    03  4  212    1.36
                  2  2  1 MISC B  12  5  213    1.45
                  2  2  1 SONU    03  1  214   17.56
                  2  2  1 MISC A  03  6  220    3.25
                  2  2  3 SEDG A  03  7  256    1.05
                  3  2  1 ANSC    03  1  221   69.20
                  3  2  1 SONU    03  4  222    0.46
                  3  2  1 ANSC    17  2  226   85.00
                  3  2  6 FORB A  03  3  227    6.59
                  3  2  1 PAVT    04  5  229    5.06
                  3  2  1 MISC B  12  6  230    1.65
                  4  2  6 FORB A  03  7  254    0.24
                  4  2  1 ANSC    03  1  231   31.15
                  4  2  1 PAVT    04  2  233    8.29
                  4  2  1 MISC B  12  4  234    1.76
                  4  2  1 ANSC    17  3  235   37.54
                  4  2  3 SEDG A  03  5  236    2.53
                  4  2  1 MISC A  03  6  253    1.51
                  5  2  1 ANSC    03  1  237   57.68
                  5  2  6 FORB A  03  2  238   18.19
                  5  2  1 PAVT    04  5  239    0.99
                  5  2  1 SONU    03  4  240    8.99
                  5  2  1 ANSC    17  3  242   83.15
                  5  2  1 MISC B  12  6  243    0.54
                  5  2  1 SPAS    03  7  245    1.72
                 11  3  1 ANSC    03  1
                 11  3  1 ANSC    19  2
                 11  3  1 SONU    03  3
                 11  3  6 FORB A  03  4
                 12  3  1 SONU    03  1
                 12  3  1 ANSC    03  2
                 12  3  1 ANSC    19  3
                 12  3  6 FORB A  03  4
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13 3 6 FORR A 03  1
13 3 1 ANSC   03  2
13 3 1 SONU   03  3
13 3 1 ANSC   19  4
14 3 1 ANSC   03  1
14 3 1 ANSC   09  2
14 3 1 SONU   03  3
14 3 1 MISC B 12  4
15 3 1 ANSC   03  1
15 3 1 ANSC   19  2
15 3 6 FORR A 03  3
15 3 1 SONU   03  4
15 3 1 MISC A 03  5
16 3 6 FORR A 03  1
16 3 1 ANSC   03  2
16 3 1 MISC B 12  3
16 3 1 SONU   03  4
16 3 1 ANSC   17  5
17 3 1 SONU   03  1
17 3 1 ANSC   03  2
17 3 1 SONU   17  3
17 3 1 ANSC   17  4
17 3 6 FORR A 03  5
17 3 1 MISC B 12  6
18 3 1 ANSC   03  1
18 3 1 PAVT   04  2
18 3 1 MISC B 12  4
18 3 1 ANSC   17  5
19 3 1 ANSC   03  1
19 3 1 SONU   03  2
19 3 1 ANSC   17  3
19 3 1 MISC B 12  4
19 3 1 MISC A 03  5
20 3 1 ANSC   03  1
20 3 1 ANSC   17  2
20 3 1 SONU   03  3
20 3 1 MISC A 03  4
20 3 1 MISC B 12  5
21 3 1 ANSC   03  1
21 3 1 ANSC   17  2
21 3 1 MISC B 12  3
21 3 6 FORR A 03  4
22 3 1 ANSC   03  1
22 3 1 ANSC   17  2
22 3 1 SONU   03  3
22 3 1 MISC B 12  4
22 3 1 SONU   17  5
23 3 1 ANSC   03  1
23 3 1 ANSC   17  2
23 3 1 MISC B 12  3
```

24	3	1	ANSC		03	1
24	3	1	SONU		03	2
24	3	1	ANSC		17	3
24	3	1	MISC	B	12	4
25	3	1	ANSC		03	1
25	3	1	PAVT		04	2
25	3	1	SONU		03	3
25	3	1	ANSC		17	4
25	3	1	MISC		12	5
26	3	1	ANSC		03	1
26	3	1	PAVT		04	2
26	3	1	MISC	B	12	5
26	3	6	FORB	A	03	3
26	3	1	ANSC		17	4
27	3	1	ANSC		03	3
27	3	1	PAVT		04	1
27	3	6	FORB	A	03	2
27	3	1	ANSC		17	4
27	3	1	MISC	B	12	5
28	3	1	SONU		03	1
28	3	1	SONU		17	2
28	3	1	SEDG		03	3
29	3	1	SONU		03	1
29	3	1	ANSC		03	2
29	3	1	PAVT		04	3
29	3	1	PAVT		17	4
29	3	1	SPAS		03	5
29	3	1	MISC	B	12	6
30	3	1	ANSC		03	1
30	3	1	ANSC		17	2
30	3	6	FORB	A	03	3
30	3	1	ANSC		19	5
30	3	1	MISC	B	12	5
30	3	1	PAVT		04	4
31	3	1	ANSC		03	1
31	3	1	SONU		03	2
31	3	1	ANSC		17	3
31	3	1	SONU		17	4
31	3	1	MISC	B	12	5
31	3	6	FORB	A	03	6
32	3	1	ANSC		03	1
32	3	1	ANSC		17	2
32	3	1	ANSC		19	3
32	3	1	MISC	B	12	4
32	3	6	FORB	A	03	5
33	3	1	ANSC		03	1
33	3	1	ANSC		19	2
33	3	1	SONU		03	3
33	3	1	ANSC		17	4
33	3	1	MISC	B	12	5
33	3	3	SEDG	A	03	6

34	3	1	ANSC		03	1
34	3	1	SONU		03	2
34	3	1	ANSC		17	3
34	3	1	ANSC		19	4
34	3	1	PAVT		04	5
34	3	1	MISC	B	12	6
35	3	1	ANSC		03	1
35	3	1	ANSC		17	2
35	3	1	ANSC		19	3
35	3	1	MISC	B	12	4
35	3	1	SONU		03	5

Litter Data

Litter data collected in 1970 at the Bison Site is Grassland Biome Data Set A2U0012. Data were collected on Form NREL-02. A copy of the form and an example of the data are attached.

IBP

GRASSLAND BIOME

U.S. INTERNATIONAL BIOLOGICAL PROGRAM

FIELD DATA SHEET - LITTER

DATA TYPE	SITE	INITIALS	DATE			TREATMENT	REPLICATE	PLOT SIZE	QUADRAT	TYPE	SACK NO.	DRY WT.	SACK WT.	ASH WT.	PREVIOUS DATE		
			Day	Mo	Yr										Day	Mo	Yr

DATA TYPE
- 01 Aboveground Biomass
- 02 Litter
- 03 Belowground Biomass
- 10 Vertebrate - Live Trapping
- 11 Vertebrate - Snap Trapping
- 12 Vertebrate - Collection
- 20 Avian Flush Census
- 21 Avian Road Count
- 22 Avian Road Count Summary
- 23 Avian Collection - Internal
- 24 Avian Collection - External
- 25 Avian Collection - Plumage
- 30 Invertebrate
- 40 Microbiology - Decomposition
- 41 Microbiology - Nitrogen
- 42 Microbiology - Biomass
- 43 Microbiology - Root Decomposition
- 44 Microbiology - Respiration

SITE
- 01 Ale
- 02 Bison
- 03 Bridger
- 04 Cottonwood
- 05 Dickinson
- 06 Hays
- 07 Hopland
- 08 Jornada
- 09 Osage
- 10 Pantex
- 11 Pawnee

TREATMENT
- 1 Ungrazed
- 2 Lightly grazed
- 3 Moderately grazed
- 4 Heavily grazed
- 5 Grazed 1969, ungrazed 1970
- 6
- 7
- 8
- 9

TYPE
- 1 Quadrat, total
- 2 Quadrat, part
- 3 Cleared plot
- 4 Litter bag

*** EXAMPLE OF DATA ***

```
         1         2         3         4         5
12345678901234567890123456789012345678901234567890123456789

0202MSM020570110.71 A01  1        130.94 26.0 012.44
                    A04  1        129.34 26.0 012.25
                    A08  1        124.45 26.0 011.67
                    A12  1        101.89 26.0 009.00
                    A16  1        214.97 26.0 022.41
                    A20  1        210.84 26.0 021.92
                    B01  1        178.88 26.0 018.13
                    B04  1        157.16 26.0 015.55
                    B08  1        102.08 26.0 009.02
                    B12  1        069.74 26.0 005.18
                    B16  1        060.34 26.0 004.07
                    B20  1        096.91 26.0 008.41
0202MSM020570120.71 A01  1        122.20 26.0 011.40
                    A04  1        145.41 26.0 014.16
                    A11  1        096.53 26.0 008.36
                    B01  1        118.72 26.0 010.99
                    B04  1        064.86 26.0 004.60
                    B08  1        200.78 26.0 020.72
0202MSM020570210.71 A01  1        019.45 4.90 001.87
                    A05  1        025.38 4.90 002.63
                    A10  1        024.72 4.90 002.54
                    A14  1        022.09 4.90 002.20
                    A18  1        022.46 4.90 002.25
0202MSM020570220.71 A01  1        047.18 4.90 005.43
                    A04  1        062.98 4.90 007.46
                    A08  1        043.14 4.90 004.91
                    A12  1        046.15 4.90 005.30
                    A20  1        049.35 4.90 005.71
                    B01  1        031.02 4.90 003.35
                    B04  1        021.90 4.90 002.18
                    B08  1        010.90 4.90 000.77
                    B12  1        015.98 4.90 001.42
                    B16  1        019.36 4.90 001.85
0202MSM150570110.71 A01  1        099.17 5.00 012.96
                    A04  1        068.52 5.00 008.74
                    A31  1        124.73 5.00 016.48
                    B01  1        027.26 1.40 003.56
                    B07  1        075.20 5.00 009.66
                    B22  1        050.19 5.00 006.22
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0202MSM150570120.71	A01	1	035.62	5.00	004.21
	A10	1	067.86	5.00	008.65
	A30	1	061.00	5.00	007.71
	B01	1	095.03	5.00	012.39
	B10	1	143.16	5.00	019.02
	B27	1	076.14	5.00	009.79
0202MSM150570210.71	A01	1	045.87	5.00	006.43
	A04	1	014.10	1.40	001.99
	A07	1	007.60	1.40	000.97
	A10	1	023.87	4.90	002.98
	A13	1	011.90	1.40	001.66
	B01	1	058.20	5.10	008.37
	B04	1	019.27	1.20	002.84
0202MSM150570220.71	A01	1	037.88	5.00	005.17
	A04	1	020.77	1.50	003.03
	B01	1	013.20	1.50	001.85
	B04	1	031.02	5.00	004.09
	B08	1	016.16	1.50	002.30
0202MSM300570110.71	A08	1	097.57	12.0	016.61
	A17	1	145.51	12.0	025.91
	B05	1	122.10	12.0	021.37
	B12	1	168.07	12.0	030.29
0202MSM300570120.71	A04	1	172.20	12.0	021.39
	A14	1	164.97	26.0	026.97
	B01	1	081.78	26.0	010.82
	B04	1	119.28	12.0	020.82
	B14	1	077.73	12.0	012.75
0202MSM300570210.71	A02	1	018.61	1.40	004.51
	A08	1	012.78	1.40	002.98
	A11	1	026.13	12.3	003.63
	B01	1	031.39	1.40	007.87
	B14	1	020.39	1.40	004.98
	B19	1	019.55	1.40	004.76
0202MSM300570220.71	A06	1	019.08	1.40	004.64
	A10	1	034.12	12.0	005.80
	A20	1	030.26	12.0	004.79
	B06	1	011.46	1.40	002.64
	B17	1	023.40	1.40	005.77