V.8 Herbage Production, Phenology, and Soil Moisture Dynamics for Plant Communities in Western North Dakota

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Increasing demand for intensive management of rangelands requires improved methodologies for classifications, descriptions, and monitoring of plant communities. It is important to document vegetation characteristics of plant communities for a reference point in order to determine how herbivory (the consumption of all or part of a plant by consumers, including cattle, wildlife, insects, etc.) affects vegetation composition and production, insects, and wildlife. An understanding of plant characteristics (production, species composition, canopy cover, phenology, degree of utilization by grazers, and abiotic factors) is important for correlation with grasshopper populations and their dynamics. Knowledge gained from the plant component will be useful in determining grasshopper relationships with vegetation characteristics. Previous vegetation studies describing habitat types and communities in western North Dakota have been limited to subjective evaluations (Hanson and Whitman 1938, Redmann 1975, Lauenroth and Whitman 1977, Hansen et al. 1984, Hansen and Hoffman 1988).

Phenology is the study of the relationship between seasonal climatic changes and plant development. Knowledge of the seasonal timing of flowering events (phenological phases) is useful information for resource managers. This information can be used to determine when to graze livestock on native pastures (Frank and Hofmann 1989), when to burn for enhancement and/or control of plant growth, and when to implement insect control measures (Hewitt 1980, Kemp et al. 1991).

An understanding of soil moisture regimes for native plant communities on the northern Great Plains is basic for improvement of rangeland productivity and development of ecological management practices for each community. On the northern Great Plains, soil moisture is one of the major factors that influence plant growth. Soil types and other factors, including plant composition, plant production, litter, grazing, rocks, and soil nutrients, influence the soil moisture (Rauzi 1960, Smika et al. 1961, Houston 1965, Goetz 1975, Cline et al. 1977, Benkobi et al. 1993). Models have been developed for plant growth at individual or homogeneous (similar) sites as related to soil moisture, precipitation, and temperature (Uresk et al. 1975 and 1979, Wight and Hanks 1981, Wight et al. 1986). However, over large areas, successful attempts to model soil moisture and plant growth relationships have been limited (Rauzi 1960). For additional information, see Branson et al. (1981) for an excellent overview of rangeland hydrology.

The objectives of this study were (1) to classify and describe plant communities quantitively by species using canopy cover, frequency of occurrence, production, and utilization of plants by herbivores in western North Dakota over a 5-year period, (2) to identify the most useful plant species for discriminating, classifying, and monitoring plant communities, (3) to provide information on phenological (growth) development for 10 native plant species, and (4) to determine seasonal trends in soil moisture for native plant communities throughout the study area.

Study Area

The study area was located on the Little Missouri National Grassland and privately owned rangelands in western North Dakota. Climate is semiarid and continental, characterized by long, cold winters and short, warm summers. The coldest month is January with an average low of 10.5 °F (–11.6 °C) and the monthly high for July is 71.6 °F (22 °C). Most of the precipitation falls as rain in early summer. Approximately 75 percent of the precipitation falls during April through September (Hansen et al. 1984, Hansen and Hoffman 1988). Yearly precipitation totals over the 5-year period for four sites within the study area are presented in table V.8–1. Vegetation is dominated by western wheatgrass *(Agropyron smithii)*, blue grama *(Bouteloua gracilis)*, needle-and-thread *(Stipa comata)*, and scarlet globemallow *(Sphaeralcea coccinea)*, with scattered dwarf sagebrush *(Artemisia cana)* and fringed sagebrush *(A. frigida)* (fig. V.8–1).

Study Methods

Plant Communities.—In all, 30 sites were selected throughout the Little Missouri National Grassland. Vegetative characteristics sampled included canopy cover and frequency of occurrence by species (Daubenmire 1959) and plants harvested at peak production. Twenty sites were sampled in 1987–88, and an additional 10 sites were added in 1989. All 30 sites were sampled in 1989–91. Each site had four replicated areas. Three transects were randomly located on each of the four replicates at each site from 1987–89. Sample size estimates for num-

Table V.8–1—Yearly precipitation, in inches, over a 5-year period for four U.S. weather service stations within the western North Dakota study area

Year	Watford City	Trotter's store	Fairfield store	Medora
1987	11	12	13	18
1988	[1]9	[1]6	8	9
1989	14	12	[1]15	[1]13
1990	11	11	12	11
1991	18	18	19	13
Average[2]			16	15

[1]Incomplete or missing data for the year.
[2]Thirty-year station average; similar measurements are not available for Watford City or Trotter's store.

Figure V.8–1—Rangelands support a variety of plant communities. Understanding how plant communities function is important for increasing knowledge about how grasshoppers interact with those communities.

ber of transects and quadrats (plots) were then determined, and for 1990–91, two 98.4-ft (30-m) permanent transects were located at random on each of the replicated sites. Canopy cover and frequency of occurrence by species were estimated at 1-m intervals within 7.9-×19.7-inch (20-×50-cm) frames along each transect (Daubenmire 1959). Data were summarized as means by site for all analyses.

Classification of Communities.—Plant communities were classified and defined by plant canopy cover and frequency of occurrence collected on the 30 sites for 1990 and 1991. Canopy cover times frequency of occurrence (index) of the 10 major plant species were subjected to data reduction (Uresk 1990) and cluster analyses (ISODATA) to determine groupings of similar plant communities (Ball and Hall 1967). Original data reductions to define the 10 major plant species were based on Soil Conservation Service range site classifications. Stepwise discriminant analysis was used to estimate the compactness of the clusters, to identify key variables that accounted for community differences, and to develop Fisher classification coefficients (Uresk 1990). Plant production estimates and utilization were summarized by plant communities.

Plant Production and Utilization.—Plant biomass at time of peak production was determined by harvesting all plants inside cages. The difference between plant biomass harvested inside and outside the cages is expressed as utilization by herbivores. Each site was comprised of four replicated areas. Prior to initiation of spring growth, 10 wire cages measuring 3.3×6.6 ft (1×2 m) were randomly located on each of the 4 replicates for a total of 40 cages/site. Plants were harvested at ground level inside each cage within one 2.69-ft^2 (0.25-m^2) randomly placed circular hoop and sorted by grasses (sedges were included in this category), forbs, and shrubs. Approximately 10–20 ft (3–6 m) from the cages, six 7.9-×19.7-inch (20-×50-cm) quadrats were harvested on each of three transects. In 1990, 5 of the 1.08-ft^2 (0.1-m^2) quadrats were harvested on each of 2 transects/replicate for a total of 10 quadrats. During 1991, a total of 10 2.69-ft^2 (0.25-m^2) circular hoops were harvested along the 2 transects. All plant material was oven dried at 140 °F (60 °C) for 48 hours and weighed to the nearest 0.1 g. Weights were expressed as a mean per site in pounds per acre.

Phenology.—Phenological development was divided into five stages: (1) vegetative, (2) flowering, (3) seed set, (4) seed drop, and (5) dormancy (Sauer and Uresk 1976). Biweekly measurements of 10 plant species were made to determine the timing of developmental stages (phenophases). For each species, 40 plants/site were randomly selected within each of 30 sites in 1989 and were monitored from mid-May through mid-August. In 1990 and 1991, 2 plants of each of the 10 species were located within each of the 4 replicates on each site for a total of 240 plants/species/year. The individual plants were permanently marked with flags in late April on each of 30 sites and were monitored through September. Although some plant species were not found on all sites, a minimum of 192 individual plants was evaluated. New plants were selected each year. Data were summarized for all sites for each of 3 years.

Soil Moisture.—In all, 28 of the study sites were sampled: 18 in 1987–88 and an additional 10 in 1989–91. At each site, four replicates were systematically selected and sampled for soil moisture at a 12-inch (30-cm) depth. On each replicate, three 40-inch soil-moisture access tubes were randomly installed in early June 1987. Neutron soil moisture probes were used and recalibrated each year. Soil samples were collected at the time of installation to determine gravimetric soil moisture. Regression analyses permitted calibration of actual gravimetric soil moisture with estimated soil moisture at each site with value converted to volume percent. Data were summarized as means per site and summarized by plant community.

Results of the Study

Plant Communities.—Cluster analyses on cover and frequency of native plant species separated the 30 sites into 4 native plant community types. Discriminant analyses indicated significant separation (P=0.001) among the plant communities. Five plant species—western wheatgrass, dwarf sagebrush, blue grama, threadleaf sedge *(Carex filifolia)* and needle-and-thread were required to separate the four native communities. The five species accounted for 97 percent of the total variation in three canonical discriminant functions.

These five major plant species were used in the discriminant procedure in SPSS/PC (1990) to develop Fisher classification coefficients to predict the four plant communities (table V.8–2). Needle-and-thread had a greater weighting for community 1, dwarf sagebrush had a greater weighting for communities 2 and 3, and western wheatgrass, a greater weighting for community 4. Based on substitution error rates in SPSS/PC (1990), the four plant communities could be classified with 96-percent accuracy given just these five species.

The four plant communities are (1) needle-and-thread/blue grama/threadleaf sedge, (2) blue grama/western wheatgrass/needle-and-thread, (3) dwarf sagebrush/blue grama/western wheatgrass, and (4) western wheatgrass/blue grama/needle-and-thread. Two additional plant communities with limited sample sizes were defined in this study but not included in the above analyses. These are (5) crested wheatgrass *(Agropyron cristatum)* and (6) dwarf sagebrush/leafy spurge *(Euphorbia esula).* The sites for each plant community by number and name are listed in table V.8–3.

Table V.8–2—Fisher classification coefficients for plant communities in western North Dakota

	Plant community			
Plant	1	2	3	4
Western wheatgrass	0.00145	0.00306	0.00384	0.00649
Dwarf sagebrush	0.00561	0.01048	0.01443	0.00417
Blue grama	0.00203	0.00649	0.00494	0.00285
Threadleaf sedge	0.00637	–0.00049	–0.00059	0.00006
Needle-and-thread	0.01095	0.00360	0.00234	0.00152
Constant	–17.48374	–17.82723	–14.53323	–13.43716

1. Needle-and-Thread/Blue Grama/Threadleaf Sedge Community.—This plant community is dominated by needle-and-thread (table V.8–4). Canopy cover for this species ranged, over a 5-year period, from 18 to 39 percent. Blue grama is the second most abundant grasslike, with canopy cover that varied from 10 to 22 percent. It was followed by threadleaf sedge, which extended from 7 to 20 percent over the 5-year period. Western wheatgrass is common in this plant community, with an overall average cover of 8 percent. Dwarf sagebrush is present only in trace amounts.

Total plant production estimated inside cages ranged from 584 lb/acre in 1988 to 1,165 lb/acre in 1991 (table V.8–5). Grasses and sedges comprised a major portion of the production in this plant community and ranged from 532 to 1,026 lb/acre. Forb production was variable and extended from 49 to 276 lb/acre. Shrubs were not dominant in this plant community; production varied from 3 to 20 lb/acre.

The difference between plant production estimated inside and outside cages (utilization) over the 5-year period is shown in figure V.8–2. In 1987, no forage utilization was evident. Utilization from 1988 to 1991 averaged 12 percent when sampled at the peak of the growing season in July.

2. Blue Grama/Western Wheatgrass/Needle-and-Thread Community.—This plant community was dominated by blue grama followed by western wheatgrass and needle-and-thread (table V.8–4). Canopy cover for blue grama ranged from 21 to 60 percent over a 5-year period. Canopy cover varied from 7 to 19 percent for western wheatgrass and from 5 to 13 percent for needle-and-thread during this study. Threadleaf sedge averaged 5 percent over the 5-year period. Dwarf sagebrush was present in only trace amounts.

Table V.8–3—List of Grasshopper Integrated Pest Management Project sites and identification number sampled, 1987–91, by plant communities in western North Dakota

1. Needle-and-thread/blue grama/threadleaf sedge	
7	101-Exclosure
15	East Twin Butte (natural)
16	Buffalo Gap
19	Dantz Creek
20	Van-Vig Ranch
22	Flat Top Butte
24	Charbonneau Creek
28	Road 881
2. Blue grama/western wheatgrass/needle-and-thread	
1	Tobacco Garden
2	Lone Beaver
3	Christ Springs
4	Bear Butte
5	Horse Creek
10	Grassy Butte
11	Devils Pass
18	Kinley Plateau
23	Valley Enclosure
26	French Creek
29	Klandl Springs
30	Bartall Creek
3. Dwarf sagebrush/blue grama/western wheatgrass	
8	Prairie Dog Enclosure
9	Little Beicegal
13	Government Creek
17	Tracy Mountain
21	Icebox Canyon
4. Western wheatgrass/blue grama/needle-and-thread	
12	Whitetail Creek
25	Bowline Creek
27	Cheney Creek
5. Crested wheatgrass	
6	Crested wheatgrass
31	East Twin (crested wheatgrass)
6. Dwarf sagebrush/leafy spurge	
14	Wannagan Creek

Table V.8–4—Mean canopy cover (percent) ± standard error for key species, by plant community and year (n=number of sites)

	1987	1988	1989	1990	1991
1. Needle-and-thread/blue grama/threadleaf sedge					
	n=5	n=5	n=8	n=8	n=8
Western wheatgrass	7.6 ± 1.4	6.9 ± 1.8	6.7 ± 1.7	5.6 ± 1.4	17.3 ± 3.3
Blue grama	13.6 ± 3.7	16.5 ± 4.2	10.0 ± 2.4	9.5 ± 2.2	22.2 ± 5.0
Threadleaf sedge	6.7 ± 2.7	11.3 ± 4.6	12.1 ± 4.2	7.3 ± 2.0	19.8 ± 8.0
Needle-and-thread	27.0 ± 8.4	17.5 ± 3.9	19.1 ± 3.6	20.3 ± 5.2	39.2 ± 6.0
Dwarf sagebrush	0.2 ± 0.2	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.1	0.4 ± 0.2
2. Blue grama/western wheatgrass/needle-and-thread					
	n=8	n=8	n=12	n=12	n=12
Western wheatgrass	8.4 ± 2.1	6.6 ± 1.4	9.5 ± 1.5	10.1 ± 1.1	19.0 ± 3.5
Blue grama	29.5 ± 2.1	24.8 ± 2.4	21.3 ± 2.2	32.3 ± 2.3	59.9 ± 3.2
Threadleaf sedge	2.1 ± 0.7	2.0 ± 0.7	4.3 ± 1.2	2.8 ± 0.6	5.0 ± 1.4
Needle-and-thread	5.6 ± 1.2	4.9 ± 1.1	4.7 ± 1.0	6.0 ± 1.5	12.5 ± 2.8
Dwarf sagebrush	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
3. Dwarf sagebrush/blue grama/western wheatgrass					
	n=4	n=4	n=5	n=5	n=5
Western wheatgrass	19.7 ± 5.8	11.0 ± 2.1	15.4 ± 2.8	13.9 ± 2.0	26.4 ± 3.8
Blue grama	15.4 ± 3.9	20.0 ± 5.0	19.1 ± 3.7	19.8 ± 5.6	38.9 ± 8.3
Threadleaf sedge	0.2 ± 0.1	0.7 ± 0.4	1.1 ± 1.0	0.5 ± 0.3	0.3 ± 0.1
Needle-and-thread	7.1 ± 1.0	5.3 ± 1.8	3.7 ± 1.0	4.1 ± 1.5	7.7 ± 3.6
Dwarf sagebrush	10.0 ± 5.3	6.4 ± 3.6	9.6 ± 3.8	9.2 ± 3.3	13.5 ± 4.9
4. Western wheatgrass/blue grama/needle-and-thread					
	n=1	n=1	n=3	n=3	n=3
Western wheatgrass	14.2	9.3	20.2 ± 3.5	20.2 ± 4.9	41.5 ± 6.5
Blue grama	24.4	37.3	14.7 ± 3.7	10.2 ± 2.8	33.5 ± 8.7
Threadleaf sedge	1.7	0.4	4.4 ± 2.5	1.1 ± 0.5	1.0 ± 0.7
Needle-and-thread	2.3	0.8	5.0 ± 2.4	6.2 ± 2.7	11.3 ± 5.8
Dwarf sagebrush	0.0	0.0	0.9 ± 0.8	0.3 ± 0.2	0.5 ± 0.4

Table V.8–5—Plant production, in total and by grasses, forbs, and shrubs (in lb/acre), over a 5-year period for six plant communities (mean ± standard error)

	1987	1988	1989	1990	1991
1. Needle-and-thread/blue grama/threadleaf sedge					
	n=5	n=5	n=8	n=8	n=8
Total	1,165 ± 96	584 ± 86	1,042 ± 102	1,113 ± 139	1,159 ± 127
Grasses	959 ± 119	532 ± 92	747 ± 75	896 ± 89	1,026 ± 120
Forbs	208 ± 40	49 ± 10	276 ± 84	207 ± 64	118 ± 24
Shrubs	7 ± 4	3 ± 2	20 ± 7	10 ± 5	16 ± 8
2. Blue grama/western wheatgrass/needle-and-thread					
	n=8	n=8	n=12	n=12	n=12
Total	984 ± 60	449 ± 18	889 ± 64	1,021 ± 57	1,144 ± 85
Grasses	733 ± 63	372 ± 19	530 ± 4	826 ± 63	1,019 ± 78
Forbs	249 ± 41	77 ± 15	351 ± 59	194 ± 28	122 ± 22
Shrubs	2 ± 1	<0.1	9 ± 4	1 ± 1	3 ± 1
3. Dwarf sagebrush/blue grama/western wheatgrass					
	n=4	n=4	n=5	n=5	n=5
Total	1,604 ± 244	401 ± 62	1,320 ± 108	1,157 ± 115	1,140 ± 112
Grasses	1,210 ± 195	334 ± 56	853 ± 98	860 ± 80	986 ± 105
Forbs	179 ± 61	30 ± 11	279 ± 96	148 ± 60	72 ± 17
Shrubs	216 ± 107	38 ± 20	289 ± 141	148 ± 73	82 ± 57
4. Western wheatgrass/blue grama/needle-and-thread					
	n=1	n=1	n=3	n=3	n=3
Total	1,271	513	1,332 ± 278	1,167 ± 183	1,308 ± 226
Grasses	878	452	825 ± 148	895 ± 112	1,154 ± 182
Forbs	390	46	459 ± 146	260 ± 96	91 ± 29
Shrubs	3	16	47 ± 45	12 ± 9	63 ± 57
5. Crested wheatgrass					
	n=2	n=2	n=2	n=2	n=2
Total	292 ± 69	391 ± 62	1,170 ± 17	1,167 ± 62	1,366 ± 249
Grasses	1,056 ± 11	377 ± 55	1,120 ± 0	1,091 ± 121	1,316 ± 285
Forbs	101 ± 51	22 ± 1	46 ± 15	72 ± 55	45 ± 30
Shrubs	16 ± 7	5 ± 5	4 ± 3	5 ± 4	6 ± 5
6. Dwarf sagebrush/leafy spurge					
	n=1		n=1	n=1	n=1
Total	2,503		2,089	1,660	2,242
Grasses	197		207	333	182
Forbs	2,055		1,405	127	1,893
Shrubs	251		477	309	168

This community was the least productive of the four major types: total plant production fluctuated from 449 to 1,144 lb/acre over the 5-year period (table V.8–5). Total production of grasses and sedges showed a range of 372 to 1,019 lb/acre. Forbs were less productive and varied from 77 to 351 lb/acre. Shrub production was very limited and averaged 3 lb/acre.

Plant production and herbivore utilization for this plant community is presented in figure V.8–3. Forage used by herbivores during the first 2 years of the study was nominal. However, plant utilization increased the last 3 years from 18 to 28 percent in July.

3. Dwarf Sagebrush/Blue Grama/Western Wheatgrass Community.—Blue grama was the dominant understory grass in this community (table V.8–4). It ranged from a low of 15 percent to a high of 39 percent canopy cover. This was followed by western wheatgrass, which varied from 11 to 26 percent cover. Dwarf sagebrush was the dominant overstory plant with canopy cover values that ranged from 6 to 14 percent over the 5-year period. Needle-and-thread averaged 6 percent canopy cover. Least abundant was threadleaf sedge, which averaged less than 1 percent cover.

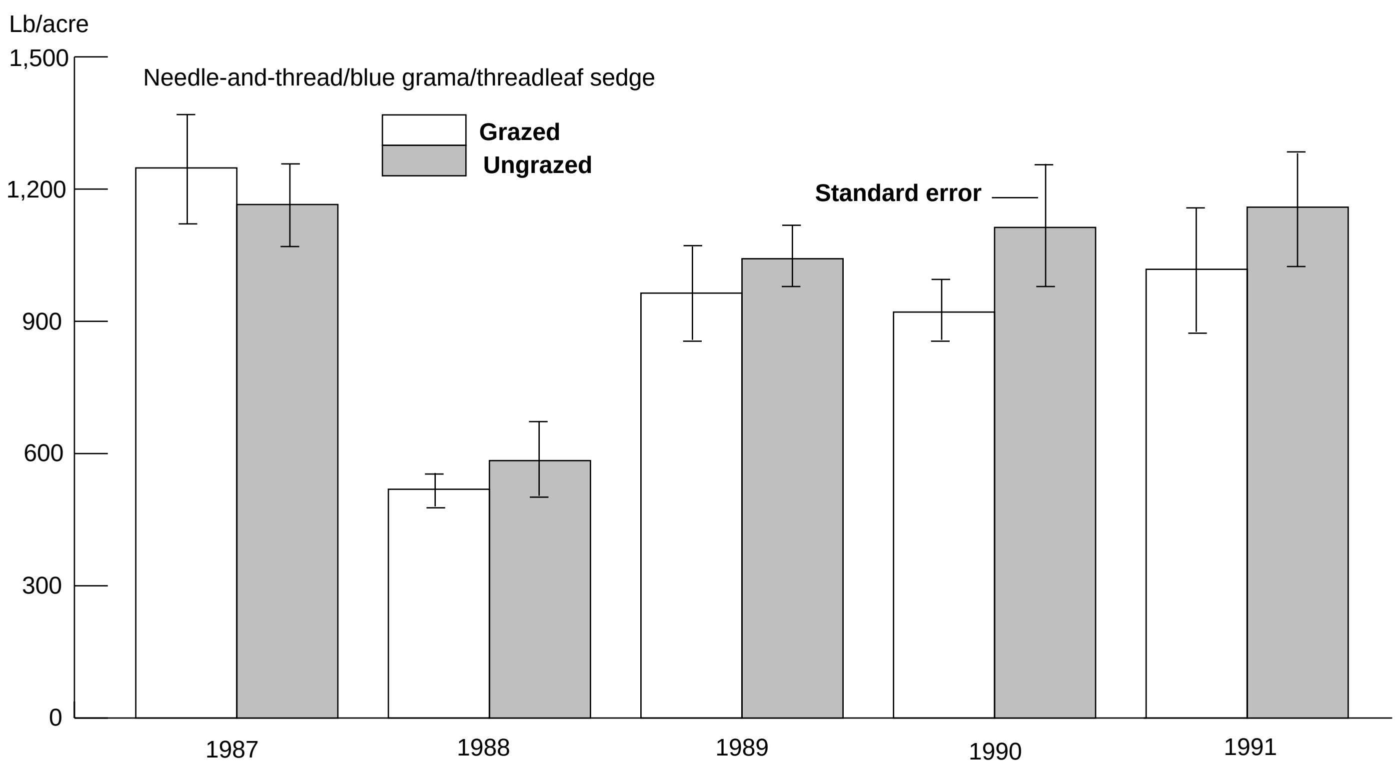

Figure V.8–2—Comparison of plant biomass in July over a 5-year period on ungrazed (inside cages) with grazed (outside of cages) habitats.

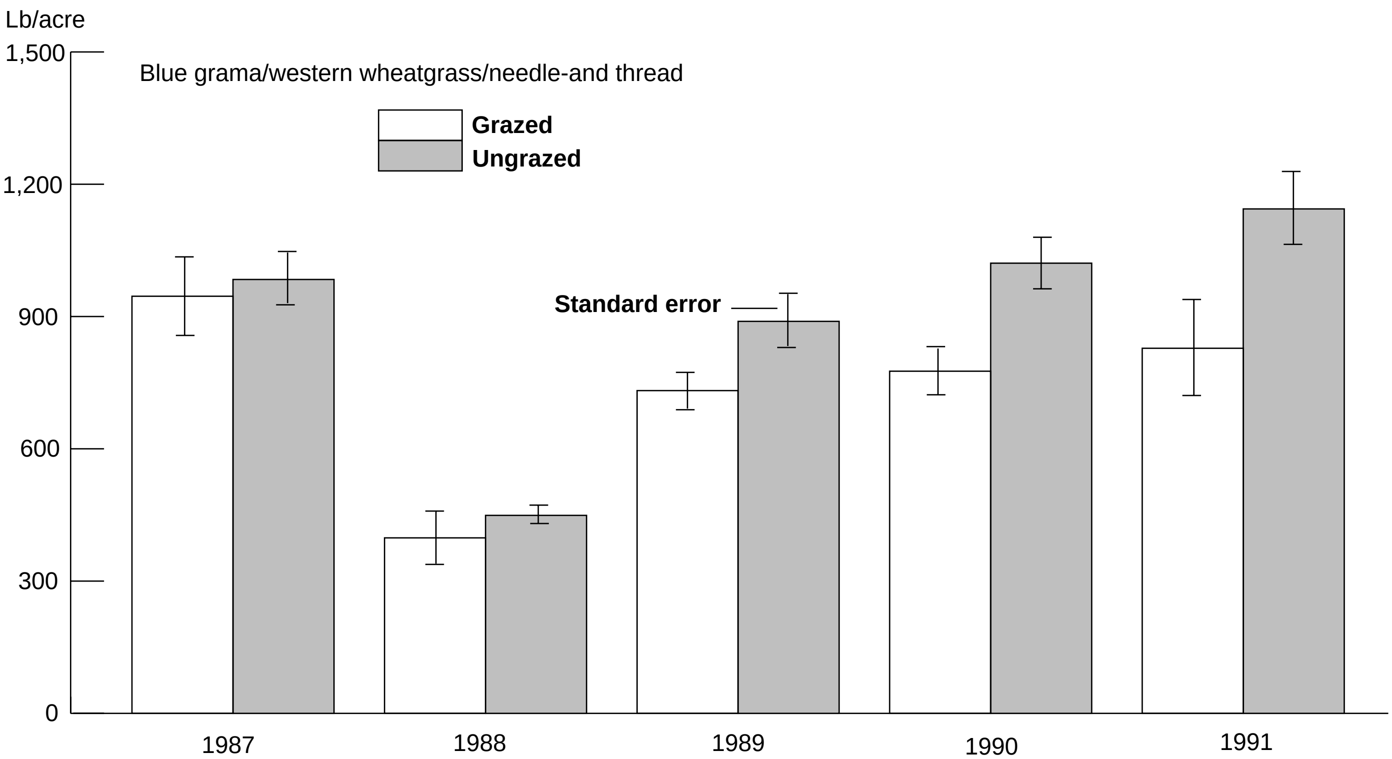

Figure V.8–3—Comparison of plant biomass in July over a 5-year period on ungrazed (inside cages) with grazed (outside of cages) habitats.

Total production ranged from 401 to 1,604 lb/acre over the 5-year period (table V.8–5). Production of grasses and sedges varied from 334 to 1,210 lb/acre. Grass and sedge production was followed by forbs with 30 to 279 lb/acre, and shrubs, with 38 to 289 lb/acre. Shrub production was greater in this community than in the other three native plant communities.

Plant utilization was nominal in light of total production estimates throughout the 5 years; however, estimates of dwarf sagebrush production were highly variable and masked utilization of grasses (and sedges) and forbs. Herbivore utilization of grasses (and sedges) and forbs is comparable to utilization in other plant communities. Utilization of grasses (and sedges) and forbs was minimal during the first 2 years (fig. V.8–4). Greatest utilization of plants occurred in 1991.

***4. Western Wheatgrass/Blue Grama/Needle-and-Thread Community.*—**Western wheatgrass was the dominant plant species in this community (table V.8–4). Canopy cover ranged from 9 to 42 percent over the 5-year period. Western wheatgrass was followed by blue grama, which ranged from 10 to 37 percent. Needle-and-thread expressed itself less (less than 1 percent cover) during the drier years early in the study; however, when more moisture was available for growth during the last 3 years, canopy cover reached a high of 11 percent. Threadleaf sedge averaged approximately 2 percent cover over the 5-year period, and dwarf sagebrush was present only in trace amounts.

Total plant production on this community ranged from 513 to 1,332 lb/acre over the 5 years (table V.8–5). Grasses and sedges showed similar trends among years, with production varying from 452 to 1,154 lb/acre. Forb production showed a range from 46 to 459 lb/acre over the study period. Shrubs were a minor component and averaged only 28 lb/acre.

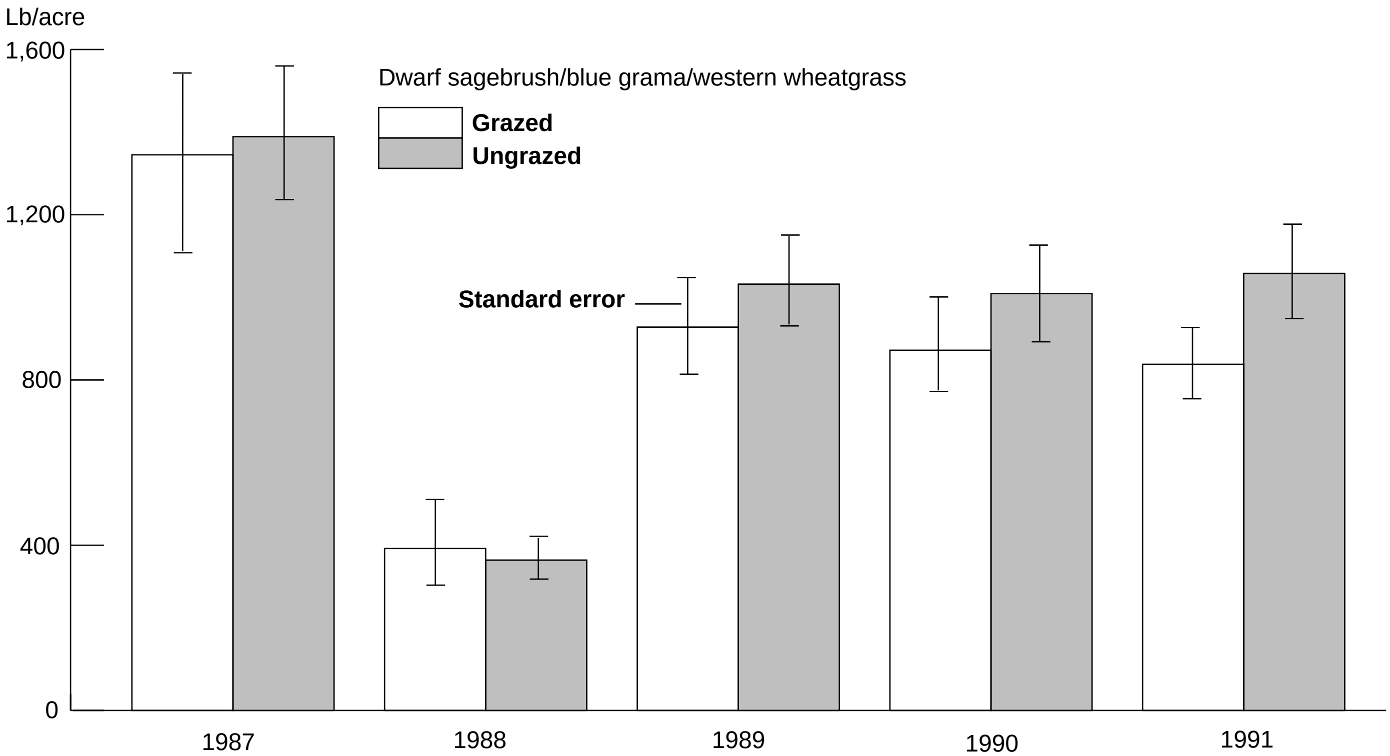

Figure V.8–4—Comparison of plant biomass in July over a 5-year period on ungrazed (inside cages) with grazed (outside of cages) habitats. Shrubs are excluded from this comparison.

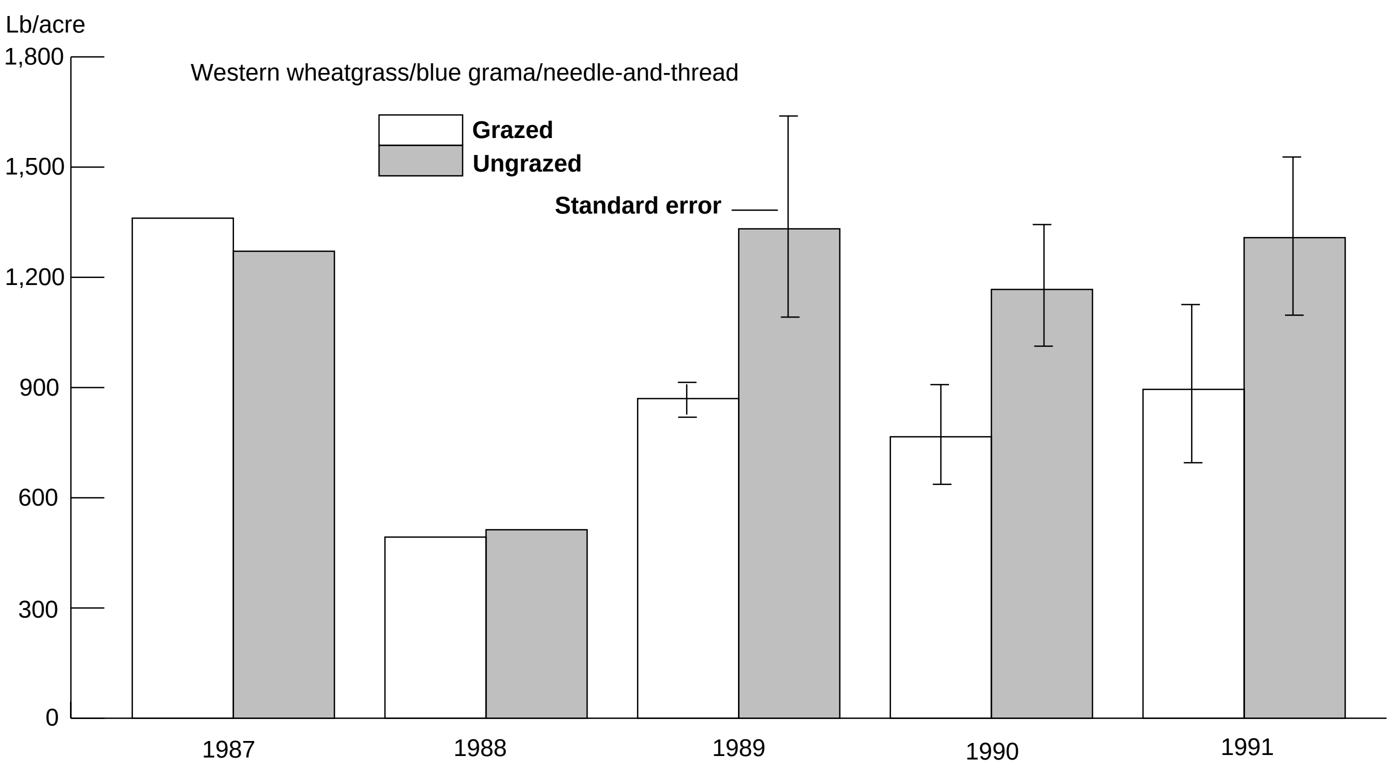

Figure V.8–5—Comparison of plant biomass in July over a 5-year period on ungrazed (inside cages) with grazed (outside of cages) habitats. For the years 1987 and 1988, n=1.

Limited sample size constrained estimates of plant utilization the first 2 years on this community (fig. V.8–5). Nominal utilization occurred in the latter 3 years. Total plant production was low during the first 2 years, but from 1989 to 1991, plant production and utilization were greater. Utilization of forage was similar during the last 3 years, averaging 34 percent. Of the four native plant communities, this one showed the greatest use by herbivores.

5. Crested Wheatgrass Community.—This plant community, represented by two sites, was dominated by the nonnative crested wheatgrass, whose canopy cover ranged from 33 to 72 percent. Needle-and-thread was the next most dominant grass, ranging from 5 to 11 percent canopy cover.

The community had been seeded to crested wheatgrass, and total plant production was less variable among years (table V.8–5). Total production for this community ranged from 391 to 1,366 lb/acre. Grass and sedge production, primarily crested wheatgrass, varied from 377 to 1,316 lb/acre. Forbs ranged in production from 22 to 101 lb/acre. Shrubs were a minor component in the community at 7 lb/acre.

Utilization of crested wheatgrass was nominal and variable throughout the study (fig. V.8–6). Livestock generally use crested wheatgrass early in the spring before native plants start to grow and then switch to native species as they turn green.

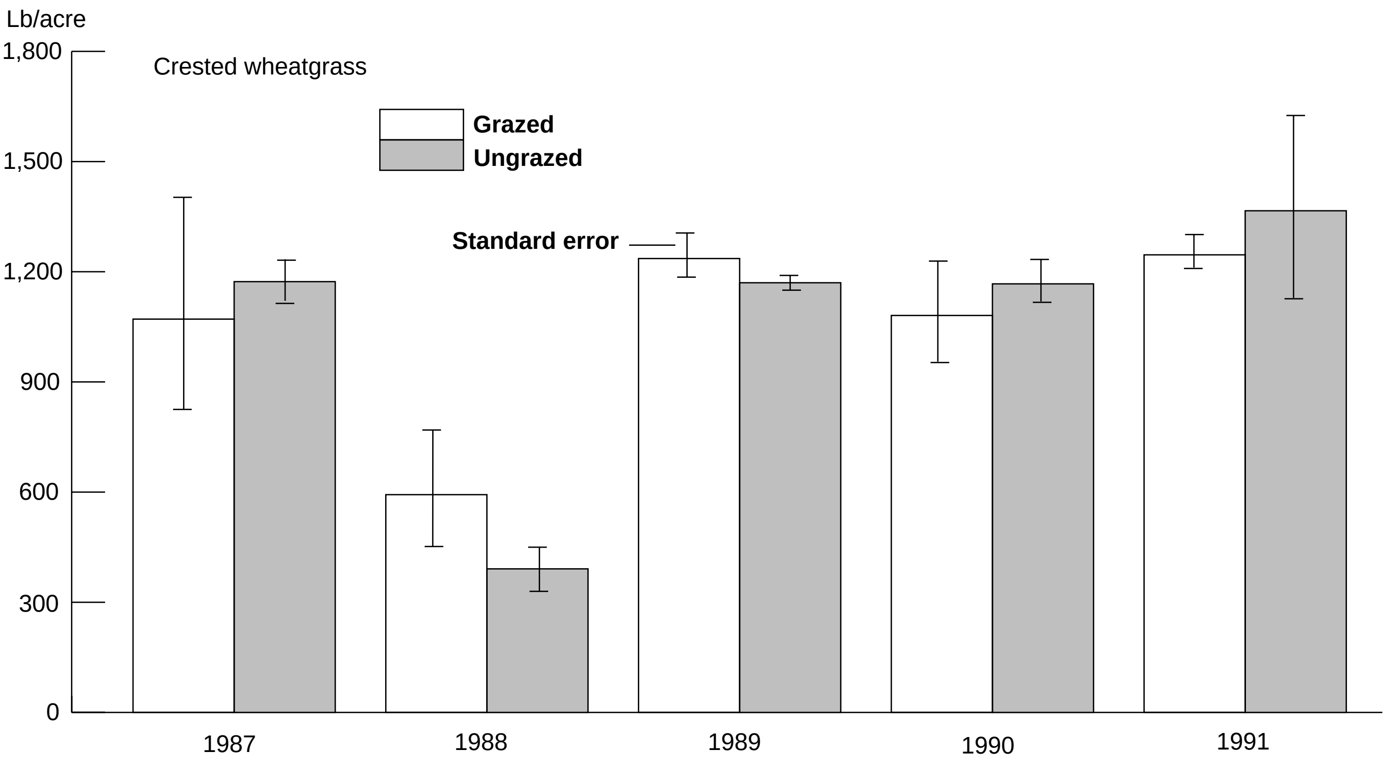

Figure V.8–6—Comparisons of plant biomass in July over a 5-year period on ungrazed (inside cages) with grazed (outside cages) habitats.

***6. Dwarf Sagebrush/Leafy Spurge Community.*—**Only one site dominated by leafy spurge was sampled throughout the 5-year period; its total understory canopy cover ranged from 50 to 77 percent. Dwarf sagebrush was the dominant shrub, and canopy cover varied from 5 to 11 percent. Some western wheatgrass (2 percent) and needle-and-thread (3 percent) was present. Total production over a 4-year period averaged 2,123 lb/acre, with forbs averaging 1,593 lb/acre, shrubs 301 lb/acre, and grasses and sedges 229 lb/acre. Plant utilization was not determined.

Phenology.—Phenological progression through the three seasons for each species is shown in figure V.8–7. These species vary in growth form and include a woody shrub, perennial grasses, *Carex* species, and a forb. The 10 species differed in the timing of their development among years. Western wheatgrass was in a vegetative stage throughout 1991; however, this plant completed all phases of development in 1990. In 1989, when other species were flowering early, fringed sagebrush remained in the vegetative state through the first week in August, when sampling was terminated. Needle-and-thread and green needlegrass *(Stipa viridula)* were similar in phenological development for all 3 years. Blue grama, junegrass *(Koeleria pyramidata)*, and Sandberg's bluegrass *(Poa sandbergii)* varied greatly among years in phenophases. Both threadleaf sedge *(Carex filifolia)* and needleleaf sedge *(C. eleocharis)* initiated flowering and seed-set early in the growing season, although length of flowering varied among years. Scarlet globemallow, a forb, flowered longer in 1989 than in the other 2 years; however, other phases of development were similar among all years. In 1991, most species entered the dormancy phase 2–4 weeks later than in 1989–90.

Extensive examination with multivariate analyses, regressions, and correlations of developmental phases through the season for the 10 plant species in our study produced no relationships with degree days, soil moisture, air temperatures, soil temperatures, or precipitation.

Soil Moisture.—Seasonal and yearly amounts of soil moisture are presented in figure V.8–8 and table V.8–6. Overall, soil moisture varied among years. When considering spring moisture available for plant growth, 1988 was the driest year and 1989 the wettest (fig. V.8–9). All years exhibited seasonal variation in soil moisture content among the four native plant communities. Generally, western wheatgrass/blue grama/needle-and-thread community (type 4) was the most moist of the four plant communities (fig. V.8–8). The driest was generally needle-and-thread/blue grama/threadleaf sedge (type 1). Soil moisture trends throughout the growing seasons differed among years. Usually soil moisture decreased on all plant communities as the growing season progressed. Soil moisture and plant production were very low in 1988. Early spring moisture content ranged from 9 to 15 percent among the four plant communities. Years showing greater amounts of soil moisture early in the growing season also showed greater plant production.

Discussion

Plant Community Classification.—The procedures developed in this study to define and classify native plant communities by methods outlined by Uresk (1990) used cover-frequency index for grouping plant communities. Individual plant communities are homogeneous, with minimal variance within each of the communities. Discriminant analyses allowed for identification of groups of variables (species) that collectively were important in separating the major communities.

Five species accounted for most of the variation (97 percent) in separating the four native plant communities in western North Dakota. The plant communities were quantitatively identified with an estimated 96 percent predictability, based on cover-frequency estimates for western wheatgrass, blue grama, threadleaf sedge, needle-and-thread, and dwarf sagebrush. Variation in species composition on a site can be used by resource managers to classify plant communities once canopy cover and frequency-of-occurrence data are collected.

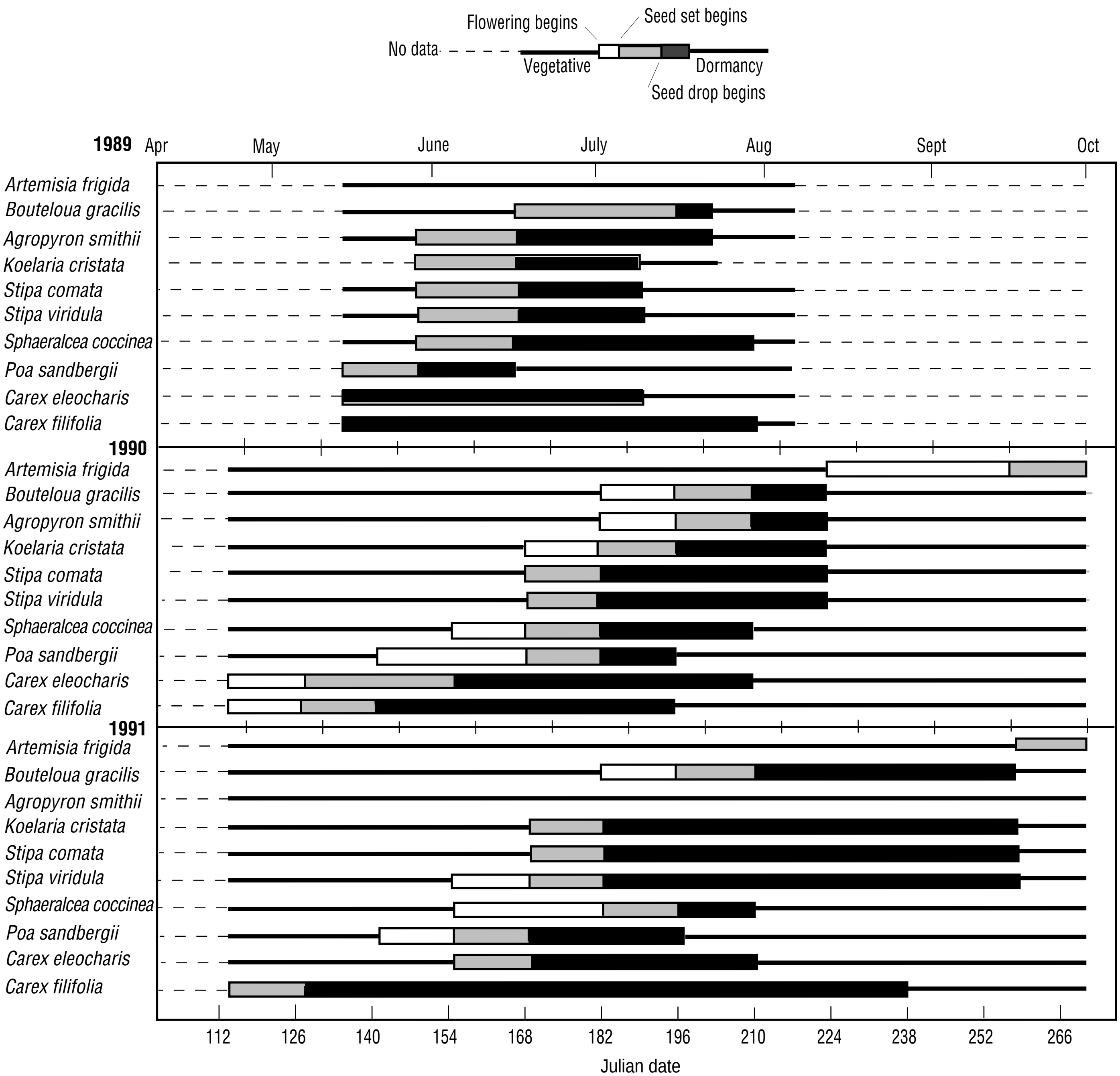

Figure V.8–7—Phenological development for 10 plant species over the 1989–91 growing seasons in western North Dakota.

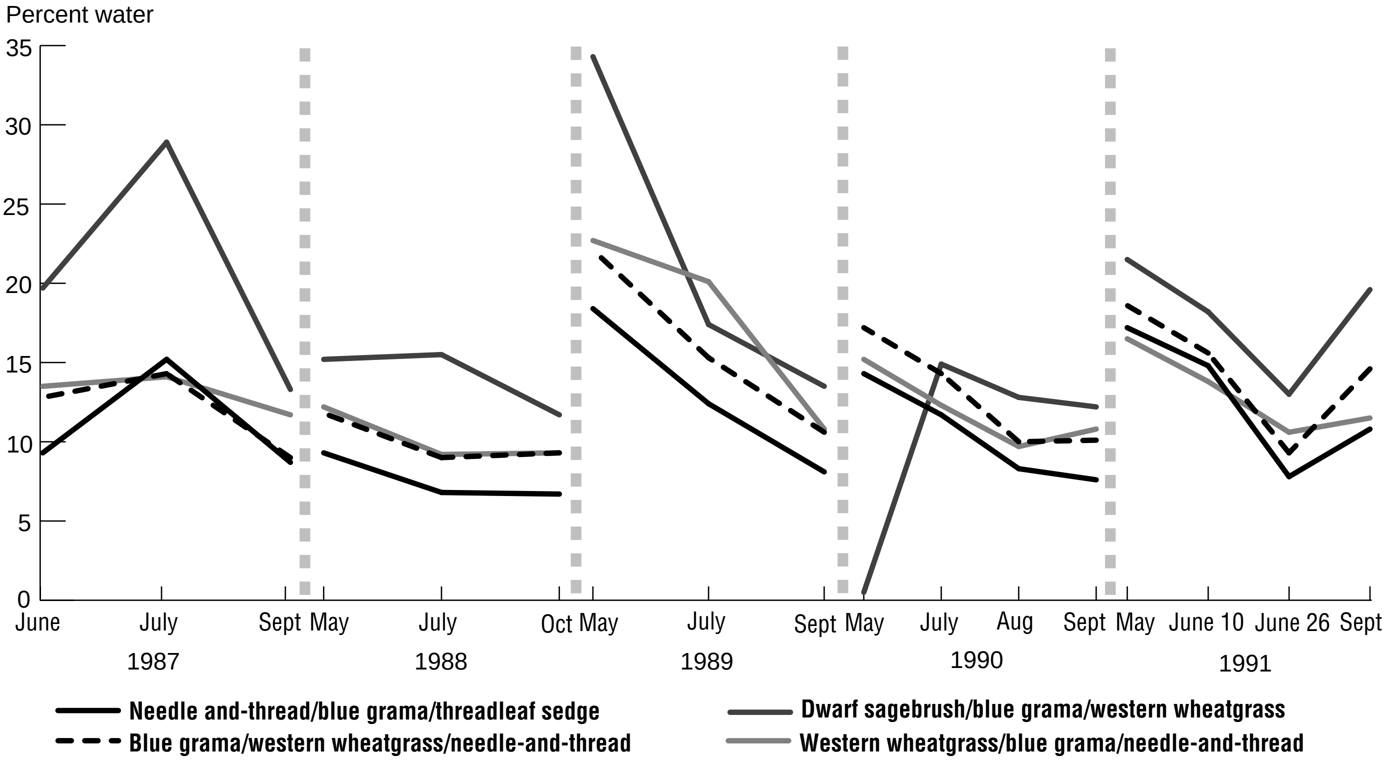

Figure V.8–8—Soil moisture content in percent, at 12-inch depth, by plant community, over a 5-year period.

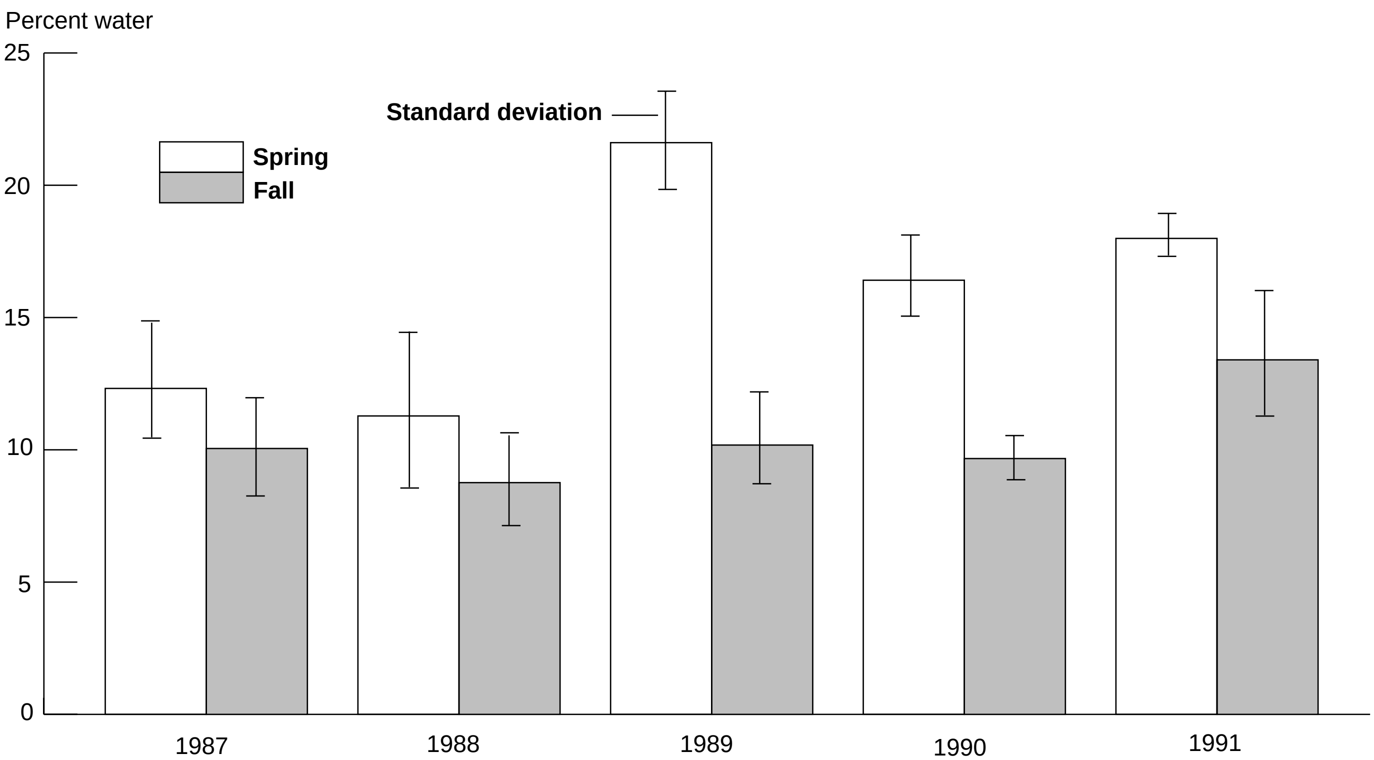

Figure V.8–9—Soil moisture content in percent, at 12-inch depth, across all sites, over a 5-year period.

Table V.8–6—Mean soil moisture (in percent; ± standard error), by plant community, over a 5-year period in western North Dakota

	[1]Type 1	Type 2	Type 3	Type 4
1987	n=5	n=8	n=4	n=1
June	9.3 ± 1.3	12.8 ± 1.9	13.5 ± 1.9	19.7
July	15.2 ± 1.7	14.3 ± 1.6	14.1 ± 2.1	28.9
Sept.	8.7 ± 0.6	9.9 ± 1.5	11.7 ± 1.5	13.3
1988	n=5	n=8	n=4	n=1
June	9.3 ± .7	11.8 ± 1.9	12.2 ± 1.6	15.2
July	6.8 ± 1.0	9.0 ± 1.6	9.2 ± 1.2	15.5
Oct.	6.7 ± .8	9.3 ± 1.7	9.3 ± 1.2	11.7
1989	n=5	n=8	n=4	n=1
1May	18.4 ± 2.7	22.1 ± 2.3	22.7 ± 3.0	34.3
July	12.4 ± 2.0	15.3 ± 2.2	20.1 ± 6.0	17.4 ± 2.4
Sept.	8.1 ± .9	10.6 ± 1.1	10.8 ± 1.2	13.5 ± 0.5
1990	n=8	n=12	n=5	n=3
May	14.3 ± 1.6	17.2 ± 0.9	15.2 ± 1.5	0.5 ± 2.0
July	11.7 ± .9	14.3 ± .9	12.3 ± 1.0	14.9 ± 1.1
Aug.	8.3 ± 1.2	10.0 ± 1.1	9.7 ± 1.1	12.8 ± .4
Sept.	7.6 ± 1.0	10.1 ± 1.1	10.8 ± 1.7	12.2 ± .6
1991	n=8	n=12	n=5	n=3
May 24	17.2 ± 1.4	18.6 ± 2.4	16.5 ± 1.0	21.5 ± 4.7
June 10	14.8 ± .6	15.6 ± 1.2	13.8 ± 1.7	18.2 ± 3.0
June 26	7.8 ± 2.5	9.3 ± 2.2	10.6 ± 2.8	13.0 ± 6.9
Sept. 18	10.8 ± 2.0	14.6 ± 1.5	11.5 ± 2.8	19.6 ± 2.9

[1] Plant community types:
1 = Needle-and-thread/blue grama/threadleaf sedge,
2 = Blue grama/western wheatgrass/needle-and-thread,
3 = Dwarf sagebrush/blue grama/western wheatgrass, and
4 = Western wheatgrass/blue grama/needle-and-thread.

Minimum requirements for data collection to classify plant communities would be to sample on two 98.4-ft (30-m) transects with a minimum of 30 frames (7.9×19.7 inches [20×50 cm]) per transect (Daubenmire 1959) for canopy cover and frequency of occurrence on each site for each of the 5 plant species. Data must be expressed as means for each of the five species. The index is obtained by multiplying canopy cover (percent) and frequency of occurrence (percent) corrected from 30 quadrats to a base of 100.

Once data are obtained for each of the five species, the method to classify a site to a plant community involves multiplying the index for each species with the appropriate Fisher classification coefficients (table V.8–2). All values are summed for each plant community, and the highest score to the positive end indicates the assigned plant community. This method, once developed, provides resource managers with a reliable quantitative tool with replicable results to classify a site to a plant community. With other methods, data sets can be interpreted subjectively to yield different results.

Monitoring Plant Communities.—The five plant species identified in the classification procedures (table V.8–2) can be used to monitor rangelands with respect to herbivory, fire, drought, and disease within these four plant communities. Monitoring can be conducted with canopy-cover and/or frequency-of-occurrence estimates with a minimum of 2 permanent transects and 30 canopy-cover and/or frequency estimates (Daubenmire 1959) per transect on each site. The index (cover × frequency) is the best plant variable to monitor changes (Uresk 1990), but either cover or frequency will do an adequate job for monitoring rangelands. Changes in direction (+/–) from the base data can be used for monitoring purposes with the five species defined for trend. Minor species are too variable for monitoring, and quantitative results are extremely limited. The five species can be easily identified and measured by resource managers in the field. Further refinement for monitoring is discussed by Uresk (1990).

Needle-and-Thread/Blue Grama/Threadleaf Sedge Community.—The eight sites assigned to this community were generally found on upland plateaus and gentle slopes. Soils were primarily sandy. Soil moisture for this community was lowest among the four communities throughout the study. In years of increased precipitation, canopy cover of some species may increase by two- or threefold. When summing canopy cover for individual species, we found that grasses and sedges ranged from 57 percent in a dry year to 125 percent in a wet year. Hansen and Hoffman (1988) reported 90 species in this community. We identified 28 grasses and sedges, 87 forbs, and 9 shrubs in this plant community, for a total of 124 species. Community and soil descriptions are similar to those provided by Hanson and Whitman (1938), Hansen et al. (1984), and Hansen and Hoffman (1988). Under heavy livestock grazing, threadleaf sedge increases and blue grama becomes dominant (Hansen and Hoffman 1988).

Plant production varied considerably from a dry year (1988) to a wet year (1991). Overall this is a very productive community. Eight species of plants make up most of the plant production for this community, with grasses (and sedges) and forbs the major components of production. Forb production showed a tremendous increase in 1989, following the dry year, possibly due to the release of nutrients available for plant growth. Hanson and Whitman (1938), Redmann (1975), and Hansen et al. (1984) described similar trends for canopy cover and production estimates for this community type.

Blue Grama/Western Wheatgrass/Needle-and-Thread Community.—Twelve sites were assigned to this community. Soils for these sites were clayey and silty. This plant community is generally found on drier upland slopes, and the period of optimum moisture for growth is shorter than that of the other communities. We found that blue grama was clearly the dominant vegetation in this plant community, similar to results reported by Hanson and Whitman (1938). Grasses and sedges ranged from 47 to 115 percent canopy cover in this community. In all, 29 grass and sedge species, 89 forbs, and 10 shrub species were identified. Redmann (1975) identified 21 species but sampled only 1 site, which produced 686 lb/acre. Overall plant production on our study ranged from 449 to 1,144 lb/acre. Forbs exhibited a 4.5-fold increase in production following 1988, the dry year. Approximately eight plant species made up the majority of the production.

Dwarf Sagebrush/Blue Grama/Western Wheatgrass Community.**—**This plant community was made up of five sites dominated by an overstory of dwarf sagebrush and an understory of blue grama and western wheatgrass. The community occupies floodplains and alluvial fans in valleys and is subjected to flooding, erosion, and deposition from storms or minor climatic events (Hanson and Whitman 1938). Soils were silty. Hansen et al. (1984) and Hansen and Hoffman (1988) described this as a dwarf sagebrush/western wheatgrass habitat type. Blue grama becomes the dominant understory plant when heavily grazed, with a reduction in western wheatgrass and needle-and-thread (Hansen et al. 1984). In the present study, grasses and sedges ranged in canopy cover from 44 to 101 percent. The number of grass and sedge species was 30; there were 69 forb species and 9 shrub species. Total production was greatest on this plant community when compared to other native plant communities; however, shrub production was highly variable. Forb production increased following the dry year.

Western Wheatgrass/Blue Grama/Needle-and-Thread Community.**—**Three sites were assigned to this plant community with western wheatgrass being the dominant plant. Soils were thinbreaks and found on slopes. Throughout the study, soil moisture was greatest for this community. Grasses and sedges ranged from 57 to 120 percent canopy cover. There were 22 grass and sedge species, 67 forb species, and 9 shrub species. Heavy livestock grazing reduces the amount of western wheatgrass and needle-and-thread and increases blue grama and buffalo grass (Uresk 1990). Grasses (and sedges) and forbs were the major component of production. Forb production increased after the dry year, 1988. Hanson and Whitman (1938) described this as a miscellaneous vegetation component in western North Dakota.

Crested Wheatgrass Community and Dwarf Sagebrush/Leafy Spurge Community.**—**Both of these communities were limited in the number of sites sampled. The crested wheatgrass community had a total of 79 plant species—23 grasses and sedges, 51 forbs, and 5 shrubs. Plant production was primarily from crested wheatgrass. Generally, in 20–30 years crested wheatgrass will decrease and native species become dominant. The dwarf sagebrush/leafy spurge site was dominated by dwarf sagebrush for the overstory plant and had an understory of leafy spurge, which land managers in the West consider a noxious weed. Total number of species in this community consisted of 10 grasses and sedges, 25 forbs, and 4 shrubs.

Phenology

Phenological change has been related to genetics, daily air temperatures, soil moisture, and nutrients (Bassett et al. 1961, Sauer and Uresk 1976, Idso et al. 1978, White 1979, Frank and Hofmann 1989, Callow et al. 1992). Plants on the northern Great Plains are dormant during winter. Seasonal development does not begin until temperatures and daylength exceed dormancy thresholds, adequate moisture is available, and no adverse conditions exist.

Most plants generally initiated flowering earliest in 1989 (fig. V.8–7) with the exception of fringed sagebrush, which remained in a vegetative state through the first week of August. In 1990, most plants were generally later in phenological development. The phases of development in 1991 exhibited a greater range for most plants throughout the season. However, western wheatgrass remained in a vegetative state. Callow et al. (1992) found that flowering events for 97 species varied by year and that temperature seemed more important than precipitation in the flowering dates of spring and early summer plants. They found that midsummer species did not show relationships to climatic effects.

Soil Moisture

Soil moisture could not be used as a variable to model plant growth and development over all 28 sites. Variation among sites was high due to variable precipitation, soil types, grazing, range condition, plant community differences, species composition, litter, and topography. Rauzi (1960) showed that correlations of soil moisture with plant production over several widely spaced sites were lower than for localized sites. Most modeling efforts in western North Dakota with acceptable results have been in homogeneous areas and with individual sites (Rauzi 1960, Wight and Hanks 1981, Wight et al. 1984 and 1986). Tools allowing management decisions to be applied over larger rangeland tracts are needed; unfortunately, it is difficult to model plant growth and development with high reliability over large areas that are highly variable.

As reported by the Agricultural Research Service in Sidney, MT, precipitation was highly variable over the study area. Effective precipitation directly influences soil moisture. Because most summer thunderstorms are localized, some areas may receive precipitation while others remain dry. However, effective thunderstorm events that recharge soil moisture were evident in some seasonal soil-moisture trends in midsummer or fall (fig. V.8–8).

Moisture-holding capacity in soil is a function of particle size. Fine soils generally accumulate and hold greater amounts of moisture; coarse-textured soils, less moisture (Houston 1965). Each plant community in our study was associated with a different soil type—a fact that accounted for some differences in soil moisture. Grazing intensity also influences the amount of moisture. Throughout the 28 sites, grazing, which varied from heavy to light, accounted for some of the variability in soil moisture among the four plant communities. Rangelands in a more productive condition with increased litter absorb greater amounts of moisture as compared to rangelands in poorer condition (Rauzi 1960, Houston 1965, Goetz 1975, Benkobi et al. 1993).

Most soil-moisture changes occur near the surface. Smika et al. (1961) and Cline et al. (1977) found that most variability in soil moisture occurred in the upper 12 inches (30 cm) with little change at the 35-inch (60-cm) depth and below. Soil moisture varied greatly among the 5 years for the four plant communities at the 12-inch depth.

Summary

The 30 sites in our study were classified into six plant communities. Multivariate analyses using the index (cover × frequency) provided a quantitative method to classify four native plant communities with key plant species for separating the communities. These plant species were western wheatgrass, blue grama, threadleaf sedge, needle-and-thread, and dwarf sagebrush. These plants may be used to monitor changes on the rangeland due to management practices, grazing, drought, fire, insects and disease.

Plant communities defined in this study were (1) needle-and-thread/blue grama/threadleaf sedge, (2) blue grama/western wheatgrass/needle-and-thread, (3) dwarf sagebrush/blue grama/western wheatgrass, (4) western wheatgrass/blue grama/needle-and-thread, (5) crested wheatgrass, and (6) dwarf sagebrush/leafy spurge. The latter two communities were limited to just a few sites.

The native grassland communities varied in soils and location. Plant community 2 showed the greatest species richness with 128 species, followed by 124, 108, and 98 for communities 1,3, and 4, respectively. Canopy cover for grasses and sedges ranged from 101 to 125 percent and was greatest on community 1, followed by 4, 2, and 3. Total production on the native communities was similar for all communities with the exception of community 2, which had lower total production. Shrub production in community 3 was highly variable. After a dry year, forb production dramatically increased the following year. Utilization was greatest on plant community 4 and least on community 3. Overall, western wheatgrass and dwarf sagebrush exhibited the greatest variability in phenological development among the 10 plant species over the 3-year period. However, yearly differences in phenological development were evident for all species. Timing for a particular developmental stage (e.g., flowering) varied by 2-4 weeks in some species over the 3 years. The wide range and variability in sites and climatic conditions did not produce definitive models for phenological development.

Soil moisture varied among years, seasons, and plant communities. Seasonal differences were pronounced in most years, with soil moisture decreasing as the growing season progressed. Plant communities dominated by western wheatgrass, blue grama, and needle-and-thread usually showed the greatest soil-moisture content; the needle-and-thread/blue grama/threadleaf sedge community showed the least over the 5-year period.

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