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Evaluating grazing strategies for cattle: Deer forage dynamics

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Abstract

We documented vegetation dynamics (April 1986–July 1989) as part of a larger study to understand botanical composition and nutritional components of cattle and deer diets under 2 grazing systems (continuous and short-duration), and 2 stocking rates (heavy and moderate) at the Welder Wildlife Refuge, Sinton, Tex. Objectives of the study were to examine initial vegetation homogeneity and floral changes over time in the plant community, and to determine phytomass dynamics. Results indicated that grazing treatment had no impact on homogeneity of the plant community. Cattle grazing, regardless of treatment, increased diversity with time until drought conditions persisted and diversity declined. Shannon's diversity index (H) changed from a pre-treatment value of H = 2.41 in April 1986, to H = 3.08 in April 1988, to H = 2.61 in April 1989. There was no difference ($P > 0.05$) in diversity index between grazing treatments or replication within years. Stocking rates (heavy = 198 g/m^2 differed ($P < 0.05$) from moderate = 258 g/m^2) had a more significant impact on phytomass than grazing system (continuous = 225 g/m^2; short-duration grazing = 231 g/m^2; $P > 0.05$) by the end of the study period. Precipitation was a determinant factor in the seasonal dynamics of phytomass of the various forage classes. Phytomass of forbs was unaffected by grazing system or stocking rate. Phytomass of grasses and grass-like plants important to deer was lower ($P < 0.05$) under short-duration than continuous grazing. Phytomass of grasses and grass-like plants preferred by deer was greater under moderate than heavy stocking rates. We recommend continuous over short-duration grazing, and moderate over heavy stocking rates, when white-tailed deer habitat quality is a primary concern. Less intensive grazing systems should be acceptable as well.

Key Words: diversity, phytomass, white-tailed deer, *Odocoileus virginianus*, cattle, Coastal Bend of Texas, short-duration grazing, continuous grazing

Resúmen

Documentamos la dinámica de la vegetación (Abril 1986 - Julio 1989) como parte de un estudio mucho mayor para tratar de entender la composición botánica y los componentes nutricionales de la dieta de vacunos y ciervos de cola blanca bajo dos sistemas de pastoreo (continuo y de corta duración), y dos cargas animales (alta y moderada) en el Refugio de Vida Silvestre Welder, Sinton, Tex. Los objetivos del estudio fueron examinar la homogeneidad inicial de la vegetación y los cambios de la flora a través del tiempo en la comunidad vegetal y a su vez determinar la dinámica de la fitomasa. Los resultados indican que los tratamientos de pastoreo no impactaron la homogeneidad de la comunidad vegetal. El pastoreo por vacunos, independiente del tratamiento, aumentó la diversidad con el tiempo hasta que la diversidad bajó debido a las condiciones de sequía. El índice de diversidad Shannon (H) cambió de un valor pre-tratamiento de 2.41 en Abril 1986, a H = 3.08 en Abril 1988, a H = 2.61 en Abril 1989. No hubo una diferencia significativa ($P > 0.05$) en el índice de diversidad entre los tratamientos o réplicas entre los años de muestreo. La carga animal (alta = 198 g/m^2 fué diferente a la moderada = 258 g/m^2) tuvo un impacto significativo mayor en la fitomasa que el sistema de pastoreo (continuo = 225 g/m^2; corta duración = 231 g/m^2) hacia fines del período de estudio. La precipitación fué un factor determinante en la dinámica estacional de la fitomasa de las diferentes clases de forraje. La fitomasa de hierbas no fué afectada por el sistema de pastoreo o la carga animal. La fitomasa de los pastos o plantas similares a pastos e importantes para los ciervos fué menor ($P < 0.05$) bajo pastoreo de corta duración que en pastoreo continuo. La fitomasa de los pastos o plantas similares a pastos y preferidas por los ciervos fue mayor bajo cargas animales moderada que cargas altas. En casos de que la calidad del hábitat para los ciervos de cola blanca sea de primordial importancia, recomendamos pastoreo contiuo en comparación a corta duración, y carga animal moderada en comparación a carga alta. Sitemas de pastoreo menos intensivos son acceptables.

Documentation of the effects of grazing strategies on vegetation is critical to determining whether these practices would result in improvement or deterioration of range condition of a particular range type or wildlife habitat. This is important when managing for more than 1 animal species, because, to obtain optimum animal production, a balance between forage supply and herbivores should be maintained (Chamrad et al. 1978).

The grazing system in which vegetation responses has been most frequently measured is continuous grazing. With the introduction of short-duration grazing, numerous studies have been conducted to compare, in terms of vegetation and animal performance, short-duration with continuous grazing using different stocking rates.

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Short-duration grazing may reduce the biomass of all categories of standing crop and litter (Heitschmidt et al. 1982) and forage availability may not be significantly different in either continuous or short-duration grazing systems (Jung et al. 1985). Heitschmidt et al. (1986) concluded that there was little evidence showing greater forage production under rotational grazing with higher than normal stocking rates than under continuous grazing with moderate stocking. Furthermore, they suggested that as stocking rate increased, herbaceous standing crop declined regardless of grazing system. Similar findings were reported by Ralphs et al. (1990). Evaluation of short-duration and continuous grazing in Mexico indicated that phytomass/animal unit was 80% greater under moderately stocked continuous grazing than twice the stocking rate under short-duration grazing (Soltero-Gardea 1987). Pitts (1983), comparing variable stocked short-duration and continuous grazing stocked steadily for 4 years, found that standing crop biomass under short-duration during the last years of evaluation was 20% less than continuous grazing.

Precipitation patterns and stocking rates have had a more significant impact on phytomass than grazing systems (Kothmann et al. 1978). Changes in species biomass have been more closely related to rainfall than grazing systems in Texas (Pitts 1983). Hart et al. (1988) suggested that differences in production among years in Wyoming were largely a result of differences in amount and timing of precipitation. Furthermore, range site, particularly soil type, can also influence the phytomass (Drawe 1988).

This research was part of a larger study on cattle and deer feeding strategies in the Coastal Bend of Texas (Ortega 1991, Soltero-Gardea 1991). The objectives of the study were to examine initial vegetation homogeneity and floral changes over time in the plant community, and to determine phytomass dynamics under 2 grazing systems, continuous and short-duration grazing, at 2 stocking rates, heavy and moderate.

Materials And Methods

Study Area

The study was conducted at the Rob and Bessie Welder Wildlife Refuge (28° 6' N, 97° 25' W), San Patricio County, Tex. The 3,157-ha refuge is located in the Coastal Bend region, a transitional zone between the Gulf Prairies and Marshes and the South Texas Plains (Box et al. 1978) (Fig. 1). The climate is humid and subtropical, with hot summers and cool winters. The Welder Wildlife Refuge has an average yearly rainfall of 89.9 cm (range = 37.5–148.7 cm). Rainfall can occur any time of the year, but usually peaks in late summer and fall. The vegetation of the area is not controlled by the average rainfall, but by the extremes. Plant growth can occur every month of the year if moisture is available (Box et al. 1978). On the study area, the Lagarto Tank area, average annual rainfall from 1962 to 1988 was 95.3 cm. In 1987, rainfall was 88.8 cm and most (41.7 cm) of it occurred during April–June. A drought occurred on the Coastal Bend during 1988, when rainfall was only 60.3 cm, most of which (32.3 cm) came during July–September. During 1989 the drought continued and the area received only 11.7 cm of rainfall in the first 6 months.

Grazing treatments were established near the Lagarto tank area. This site was chosen based on homogeneity of the mesquite-mixed grass plant community. This community is found throughout the region, on poorly drained Victoria clay soils (Drawe et al. 1978). It is characterized by moderate stands of honey mesquite

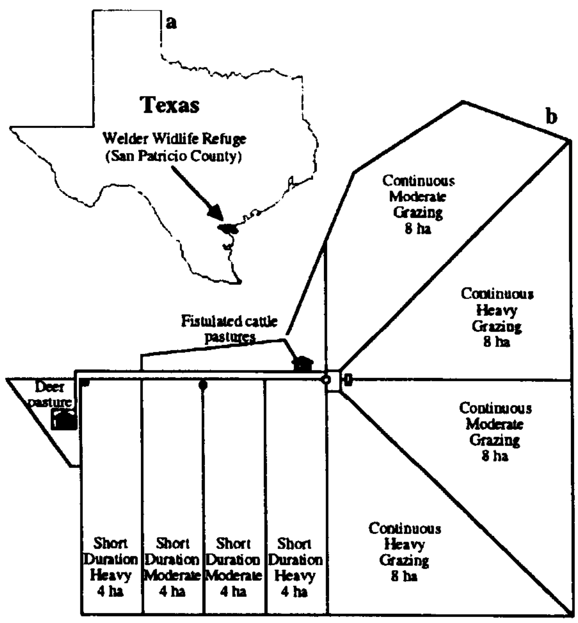

Fig. 1. (a) Texas location of study area and (b) design and distribution of treatment pastures and replications. Welder Wildlife Refuge, San Patricio Co., Texas, 1986–1989.

(*Prosopis glandulosa* Torr.), interspersed with mottes of brasil (*Condalia hookeri* M.C. Johnst.) and Texas persimmon (*Dyospiros texana* Scheele.). Buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.), pink tridens (*Tridens congestus* (L.H. Dewey) Nash.), and bermudagrass (*Cynodon dactylon* (L.) Pers.) are the dominant grasses. Among the forbs, prairie coneflower (*Ratibida columnaris* Sims), western ragweed (*Ambrosia psilostachya* DC.), clay violet (*Ruellia nudiflora* (Gray) Urban), and patches of wood-sorrel (*Oxalis dillenii* Jacq.) were dominant. Sumpweed (*Iva annua* L.) was a dominant annual forb, for a few months after heavy rains in June 1987. Botanical names and plant identification follow taxonomy by Gould and Box (1965) and Jones (1982).

Soils are vertisols of the Victoria series (fine, montmorillonitic, hyperthermic, Udic Pellustert), with slopes of 0–1% and poorly drained. According to their texture, soils are classified as clayey (Drawe et al. 1978).

Treatments

The study area consisted of 48 ha divided into 4 study sites (Fig. 1). One site of 8 ha was a short-duration grazing with 2 replications (4 ha/replicate) at a heavy stocking rate (1 AU/2.4 ha/yr). A second site of 8 ha contained two 4 ha replicates of short-duration grazing at a moderate stocking rate (1 AU/4.9 ha/yr). On a third adjacent (16 ha) site, we established a continuous grazing treatment with 2 replications of 8 ha each at heavy stocking (1 AU/2.4 ha/yr); whereas, the fourth site had 2 replications (8 ha each) of continuous grazing with moderate stocking (1 AU/4.9 ha/yr).

Vegetation Measurements

Data were collected from October 1987 to July 1989; a pretreatment sampling was done in April 1986 prior to implementing the grazing treatments in March 1987. To better interpret seasonal variation under the different treatments, monthly sampling periods were grouped into seasons. October and November were considered to be the fall season; December, January, and February were the winter season; March and April were grouped into a spring season; and May through September were merged into the summer season. Summer season 1989 included only May, June, and July. Precipitation at the study site was recorded during 1987, 1988, and 1989.

We read fifty, 0.25-m^2 randomly selected quadrats per treatment replication, for presence/absence of plant species (species frequency) to document changes in availability and floral diversity. These data were collected each month in all treatment replications 2 days before grazing the short-duration treatment. To minimize observer error, data collection was done by one observer.

The point-centered quarter method (Dix 1961) was used to estimate relative frequency of woody vegetation. Sampling was conducted from 8 to 14 August 1988. A total of 10 randomly selected line transects was sampled using 5 points in each line, totaling 50 points per treatment replication.

Phytomass dynamics were determined by hand-clipping 10 randomly located 0.25-m^2 rectangular plots in each pasture every month (Cook and Stubbendieck 1986). Samples collected were frozen and later separated to obtain biomass by forage classes. Samples were sorted and oven dried for 72 hours at 55°C for air dry weight determinations. Eight forage classes were recognized: preferred grasses, non-preferred grasses, preferred forbs, non-preferred forbs, preferred grass-like species, non-preferred grass-like species, litter, and total phytomass. Species were classified as preferred and non-preferred by deer, based upon previous research at the study site (Drawe 1968; Drawe and Box 1968; Chamrad et al. 1978). Total phytomass was calculated as the sum of all plant groups.

Shannon's diversity index (H) (Magurran 1988) was calculated from frequency data to measure species richness and evenness of the study area. These diversity indices were calculated for April 1986, prior to implementing grazing treatments, and again in April of 1988 and 1989.

Statistical Analysis

Data on phytomass of forage classes and species were analyzed using a General Linear Model (GLM) of Statistical Analysis

Table 1. Seasonal availability (percent frequency) of forage in the continuous grazing treatment under heavy and moderate stocking rate. Only species with a relative frequency > 5% in any 1 season are presented.

	Heavy									Moderate								
	1987	1988				1989				1987	1988				1989			
	fall	winter	spring	summer	fall	winter	spring	summer	Mean	fall	winter	spring	summer	fall	winter	spring	summer	Mean
	(%)									(%)								
Forbs																		
Ambrosia psilostachya DC.	13.1	9.8	7.6	5.0	3.7	3.1	2.7	0.5	5.7	11.1	8.0	6.0	5.4	3.8	3.8	5.6	1.7	5.7
Desmanthus virgatus (L.) Willd.	2.6	0.1	0.4	4.3	2.3	0.2	4.4	4.2	2.3	2.0	–	0.3	3.1	2.7	–	4.6	4.1	2.1
Euphorbia spathulata Lam.	–	2.9	5.0	–	–	–	0.3	–	1.0	–	2.8	5.1	–	–	0.2	–	–	1.0
Geranium carolinianum L.	–	9.5	5.5	–	–	1.3	0.2	–	2.1	–	9.7	7.7	–	0.1	1.9	0.5	–	2.5
Iva annua L.	14.0	–	1.9	1.4	0.3	0.2	–	0.3	2.3	18.1	0.3	1.0	1.1	0.4	1.0	0.5	–	2.8
Lesquerella lindheimeri (Gray) Wats.	–	–	4.6	0.8	3.1	12.0	5.1	–	3.2	–	–	3.1	0.7	1.0	8.2	4.4	–	2.2
Lythrum californicum Torr. and Gray	0.2	4.8	5.0	3.9	2.9	4.9	0.6	0.8	2.9	0.4	4.6	5.6	3.4	2.9	5.2	0.6	0.7	2.9
Marsilea macropoda A. Br.	0.9	1.2	3.4	3.7	3.6	0.8	3.0	1.1	2.2	2.2	2.1	2.2	4.2	3.5	1.9	1.6	2.0	2.5
Oenothera speciosa Nutt.	0.3	2.8	6.0	1.6	1.4	2.4	–	–	1.8	0.1	3.2	7.8	1.4	1.1	2.9	0.3	–	2.1
Oxalis dillenii Jacq.	0.4	3.1	2.9	5.4	3.9	5.4	1.8	0.5	2.9	0.2	2.3	3.1	6.2	4.4	6.6	2.8	1.2	3.4
Phyla incisa Small	5.1	1.4	1.4	3.9	5.7	3.5	7.6	6.7	4.4	5.3	2.6	1.2	5.0	7.6	5.3	5.9	10.8	5.5
Phyla nodiflora (L.) Greene	3.6	1.5	1.0	4.1	3.7	4.2	2.2	7.6	3.5	1.5	1.9	1.7	3.7	4.3	2.1	2.6	4.9	2.8
Pyrrhopappus multicaulis DC.	–	8.3	4.5	0.2	–	0.4	–	–	1.7	–	7.7	4.2	–	–	0.1	–	–	1.5
Ratibida columnaris (Sims) D. Don.	5.0	13.4	9.3	5.1	3.2	3.8	3.0	–	5.4	5.3	11.7	8.3	5.5	5.2	6.6	4.2	–	5.9
Ruellia nodiflora (Gray) Urban	9.7	2.6	3.6	10.0	11.6	2.9	6.5	13.8	7.6	9.9	3.4	3.0	10.5	9.0	2.2	5.5	15.4	7.4
Other Forbs	15.5	12.8	12.4	15.0	14.2	8.7	20.8	15.1		15.1	12.8	12.2	13.9	13.0	7.6	17.6	14.7	
Total Forbs	70.6	74.2	74.4	64.4	59.6	53.9	58.2	50.6		71.1	73.2	72.5	64.2	59.0	55.5	56.7	55.5	
Grasses and Grass-like																		
Buchloe dactyloides (Nutt.) Engelm.	10.5	12.0	7.9	16.5	17.3	24.1	13.3	41.7	17.9	8.9	9.3	5.8	12.5	17.1	19.6	10.6	31.1	14.4
Cyperus acuminatus Torr. and Hook.	5.9	4.2	3.9	4.3	6.5	5.6	5.0	2.1	4.7	7.5	5.1	4.4	4.8	6.8	6.5	4.3	2.7	5.3
Hordeum pusillum Nutt.	–	–	6.3	–	–	–	2.9	–	1.2	–	–	6.7	–	–	–	3.1	–	1.2
Schizachyrium scoparium (Michx.) Nash	–	–	–	–	–	–	–	–	–	0.1	–	0.1	0.4	0.2	0.5	–	0.6	0.2
Scirpus saximontanus Fern.	–	1.7	0.1	0.9	0.7	3.9	0.1	–	0.9	–	1.7	–	0.6	0.7	4.9	0.1	–	1.0
Sporobolus asper (Michx) Kunth.	–	–	–	–	3.8	–	–	–	0.5	–	–	–	–	5.3	0.3	–	0.2	0.7
Stipa leucotricha Trin. and Rupr.	–	–	0.4	1.0	2.6	9.6	17.8	0.6	4.0	–	–	1.1	0.7	0.8	7.6	16.4	–	3.3
Tridens congestus (L. H. Dew.) Nash.	9.6	3.9	5.1	7.6	2.6	0.8	0.6	3.7	4.2	10.4	6.2	7.0	9.8	2.3	2.3	3.5	7.4	6.1
Other Grasses and Grass-like	3.5	4.0	1.8	5.2	6.9	2.2	2.1	1.3		2.0	4.5	2.5	7.1	7.7	2.7	5.2	2.4	
Total Grasses and Grass-like	29.4	25.8	25.6	35.7	40.4	46.1	41.8	49.4		28.9	26.8	27.5	35.8	41.0	44.5	43.3	44.5	

System (SAS 1985) through a completely randomized design, with a split-plot in time arrangement (Steel and Torrie 1980). Pastures within grazing systems (GS) and stocking rate (SR) were considered replications (Rep). Grazing systems and stocking rates were whole plots with seasons as the split-plot. The error term for testing significant effects of grazing systems and stocking rate was Rep × SR (GS). The error term used for testing season was Rep × GS × SR × Seasons. Differences between means were determined using Fisher's protected least significant difference (LSD) procedure (alpha level = 0.05) (Ott 1988).

Results and Discussion

Study Area Homogeneity and Floral Changes

Prior to initiation of grazing treatments, sampling of the herbage layer conducted in April 1986 showed a mean diversity index of H = 2.41 for all treatment pastures. There was no difference in diversity ($P > 0.05$) among treatment pastures, with diversity indices ranging from H = 1.95 to H = 2.63. However, there was an increase in diversity in all pastures by April 1988 (H = 3.08) and a decrease in diversity in April 1989 (H = 2.61). Diversity across all treatment pastures was similar ($P > 0.05$) in April 1986 and April 1989, but it was different ($P < 0.05$) between these 2 dates and April 1988. There was no difference ($P > 0.05$) in diversity among pasture treatments or replications within years.

Grazing treatments did not affect species composition of the vegetation in the study area; species richness and evenness was maintained. Evidently, short-term (2 yr) changes in the vegetation composition did not occur because of grazing impacts or treatments. The increase of 1 perennial species, wood-sorrel, was directly related to opening the herbage canopy by grazing, drought of the second year, and moderate stocking rate. Soltero-Gardea (1991) confirmed the findings of several other studies where heavy stocking rates have more impact on biomass than grazing systems.

Most species were affected in their availability by season ($P < 0.05$) (Tables 1 and 2). Some species were affected by the grazing system (i.e., western ragweed). While some were affected by grazing system, stocking rate, or seasonal interactions. We observed an unexplainable

Table 2. Seasonal availability (percent frequency) of forage in the short-duration grazing treatment under heavy and moderate stocking rate. Only species with a relative frequency > 5% in any 1 season are presented.

	Heavy									Moderate								
	1987	1988				1989				1987	1988				1989			
	fall	winter	spring	summer	fall	winter	spring	summer	Mean	fall	winter	spring	summer	fall	winter	spring	summer	Mean
	(%)									(%)								
Forbs																		
Ambrosia psilostachya DC.	15.5	11.7	9.6	9.0	8.7	7.8	5.8	0.8	8.6	14.7	11.0	8.8	9.1	8.0	8.7	8.0	2.8	8.9
Desmanthus virgatus (L.) Willd.	1.2	0.1	0.3	3.0	1.8	-	4.0	4.9	1.9	1.9	–	1.1	4.2	2.0	–	3.6	5.6	2.3
Euphorbia spathulata Lam.	–	2.2	5.7	–	–	0.3	–	–	1.0	–	2.2	4.7	–	–	0.5	0.6	–	1.0
Geranium carolinianum L.	–	10.1	7.5	–	–	2.5	0.2	–	2.5	–	11.1	7.5	–	–	3.7	0.3	–	2.8
Iva annua L.	17.8	0.3	2.1	2.4	1.0	0.3	0.6	–	3.1	19.2	0.1	1.6	2.9	1.0	0.9	1.1	0.3	3.4
Lesquerella lindheimeri (Gray) Wats.	–	–	1.8	0.5	2.7	12.3	5.7	0.2	2.9	–	–	1.9	0.4	0.7	7.1	3.0	–	1.6
Lythrum californicum Torr. and Gray	0.2	7.8	5.0	3.7	4.3	5.4	0.5	1.2	3.5	–	5.5	5.0	3.1	3.1	3.8	0.8	1.3	2.8
Marsilea macropoda A. Br.	1.3	1.1	3.4	5.7	3.3	0.6	2.4	4.1	2.7	1.5	1.6	3.3	5.4	2.2	1.3	2.8	4.3	2.8
Oenothera speciosa Nutt.	0.6	3.0	5.3	1.9	2.0	5.0	1.1	–	2.4	0.5	4.2	6.9	2.3	1.3	5.6	0.7	–	2.7
Oxalis dillenii Jacq.	0.1	1.5	2.8	7.3	3.8	5.5	3.0	3.7	3.5	0.3	1.4	2.8	6.2	4.2	6.7	1.9	2.2	3.2
Phyla incisa Small	4.0	0.7	1.1	3.4	6.2	4.0	6.6	7.7	4.2	2.2	1.1	0.8	2.3	4.4	2.5	2.1	2.9	2.3
Phyla nodiflora (L.) Greene	–	5.9	5.7	0.4	–	–	0.1	1.5	–	5.7	5.9	0.2	–	–	–	–	–	1.5
Pyrrhopappus multicaulis DC.	0.7	0.4	0.4	1.5	1.8	1.0	2.5	3.5	1.5	1.0	0.3	0.1	2.2	2.6	2.0	1.4	3.8	1.7
Ratibida columnaris (Sims) D. Don.	1.9	11.4	6.9	5.0	3.8	3.5	4.2	0.4	4.6	1.8	10.8	6.8	4.2	2.5	6.0	4.5	0.5	4.6
Ruellia nodiflora (Gray) Urban	6.2	2.2	2.2	7.6	7.0	1.7	5.1	14.1	5.8	6.5	3.5	2.6	6.8	6.4	1.6	4.6	12.5	5.6
Other Forbs	13.9	9.2	12.6	11.5	12.1	7.0	19.1	15.9		14.8	11.0	14.5	12.3	14.4	6.5	20.3	17.6	
Total Forbs	63.5	67.6	72.3	62.9	58.5	56.8	60.7	56.4		64.2	69.5	74.2	61.7	52.8	56.9	55.5	53.9	
Grasses and Grass-like																		
Buchloe dactyloides (Nutt.) Engelm.	7.9	9.7	5.1	13.6	15.9	19.8	10.7	28.4	13.9	6.3	8.1	4.5	11.6	14.5	16.3	9.3	25.3	12.0
Cyperus acuminatus Torr. and Hook.	5.8	6.8	4.0	3.6	4.9	5.4	4.0	2.8	4.7	7.8	7.4	3.0	4.0	4.9	6.5	3.6	3.7	5.1
Hordeum pusillum Nutt.	–	–	4.1	–	–	–	1.9	–	0.8	–	–	4.4	–	–	–	3.2	–	1.0
Schizachyrium scoparium (Michx.) Nash	8.2	5.4	3.5	4.3	4.4	5.4	2.4	6.8	5.1	4.2	3.6	2.6	3.0	3.1	3.7	1.2	3.8	3.2
Scirpus saximontanus Fern.	–	3.0	0.9	0.8	1.1	5.5	0.2	–	1.4	–	2.5	0.4	0.2	1.0	6.1	0.1	–	1.3
Sporobolus asper (Michx) Kunth.	–	–	-	–	5.2	–	–	–	0.7	–	–	–	–	8.2	1.0	–	–	1.2
Stipa leucotricha Trin. and Rupr.	–	–	0.3	0.6	0.4	4.0	13.8	0.1	2.4	–	–	0.6	0.1	0.8	4.6	16.7	0.5	2.9
Tridens congestus (L. H. Dew.) Nash.	10.1	5.9	7.6	7.7	2.2	1.2	1.6	4.2	5.1	12.6	6.2	8.7	11.5	3.7	3.3	3.3	11.5	7.6
Other Grasses and Grass-like	4.5	1.8	2.3	6.5	7.5	2.0	4.7	1.3		4.9	2.7	1.7	7.9	10.9	1.7	7.1	1.3	
Total Grasses and Grass-like	36.5	32.4	27.8	37.1	41.5	43.2	39.3	43.6		35.8	30.5	25.8	38.3	47.2	43.1	44.5	46.1	

interaction grazing system × stocking rate × season for purple vetch (*Vicia leavenworthii* Torr. and Gray) and meadow dropseed (*Sporobolus asper* (Michx.) Kunth.), an unexplainable interaction grazing system × stocking rate for rastyseed paspalum (*Paspalum langei* (Fourn) Nash.), and an unexplainable interaction grazing system × season for pepperwort (*Marsilea macropoda* A. Br.), pink evening primrose (*Oenothera speciosa* Nutt.), and little barley (*Hordeum pusillum* Nutt.)($P < 0.05$) (Tables 1 and 2).

From the herbage layer, the response of some plant species frequently used by cattle and deer were highlighted to illustrate heterogeneity of the treatments. Buffalograss increased ($P < 0.05$) on all treatments throughout the study. Pink tridens was more abundant in the moderate than the heavy treatments during fall 1987, winter 1988, and spring 1989 ($P < 0.05$). Texas wintergrass (*Stipa leucothricha* Trin. and Rupr.) was available in greater proportions in the continuous grazing than short-duration grazing treatments during winter 1989 ($P < 0.05$) (Table 1 and 2).

Among the forbs, bladderpod (*Lesquerella lindheimeri* (Gray) Wats.) was more abundant under continuous grazing than short-duration grazing ($P < 0.05$) (Table 1 and 2). Prairie coneflower showed a steady decline throughout the study in all treatments starting in winter 1988 ($P < 0.05$) (Tables 1 and 2). We observed greater availability of wood-sorrel in the heavy compared to the moderate treatments in spring 1989 ($P < 0.05$) (Tables 1 and 2).

Analysis of the browse layer showed that several species were similarly available throughout the area, regardless of grazing treatment. Mesquite was the most abundant brush species on the study area (65%; range = 62 – 67%), followed by huisache (*Acacia farnesiana* Isely) (15%; range = 10 – 19%).

Phytomass Dynamics

No differences ($P > 0.05$) were found between grazing systems in total phytomass by the end of the study (Table 3). When forage classes were analyzed, we found differences ($P < 0.05$) between grazing systems for preferred grasses, grass-like plants, and litter. Under continuous grazing, phytomass of preferred grasses was 13% greater and grass-like plants was 56% greater, than under short-duration grazing. Litter, on the other hand, was 15% greater under short-duration grazing than under continuous grazing. In the short-duration grazing pastures, there was a slightly greater frequency of little bluestem (*Schizachyrium scoparium* (Michx.) Nash), a midgrass species, that produces large amounts of foliage and litter (Tables 1 and 2). This factor, combined with periodic rest of the pastures, may have contributed to an accumulation of litter, particularly under short-duration grazing.

When we compared stocking rates, no differences ($P > 0.05$) were found between non-preferred plant forms (forbs, grasses, and grass-like) (Table 3). However, total phytomass was 14% greater under moderate than under heavy stocking rate. Phytomass of preferred grasses, preferred grass-like, and litter

Table 3. Mean phytomass of plant groups (g/m^2) preferred and non-preferred by white-tailed deer, after 3 years of livestock use under different grazing systems and stocking rates at the Welder Wildlife Refuge.

	Grazing Systems		Stocking Rate	
Plant Groups	Continuous	Short-duration	Heavy	Moderate
	(g/m^2)			
Forbs				
Preferred	27.5 a[1]	23.1 a	26.4 a	24.1 a
Non-preferred	22.4 a	20.8 a	22.1 a	21.1 a
Grasses				
Preferred	58.5 a	50.6 b	45.7 b	63.8 a
Non-preferred	0.8 a	0.4 a	0.4 a	0.7 a
Grass-like				
Preferred	3.7 a	1.6 b	2.0 b	3.3 a
Non-preferred	0.2 a	0.2 a	0.1 a	0.2 a
Litter	112.7 b	133.1 a	102.6 b	143.3 a
Total	224.5 a	231.1 a	198.0 b	257.6 a

[1]Means with the same letter between grazing systems and between stocking rates are not significantly different ($P > 0.05$).

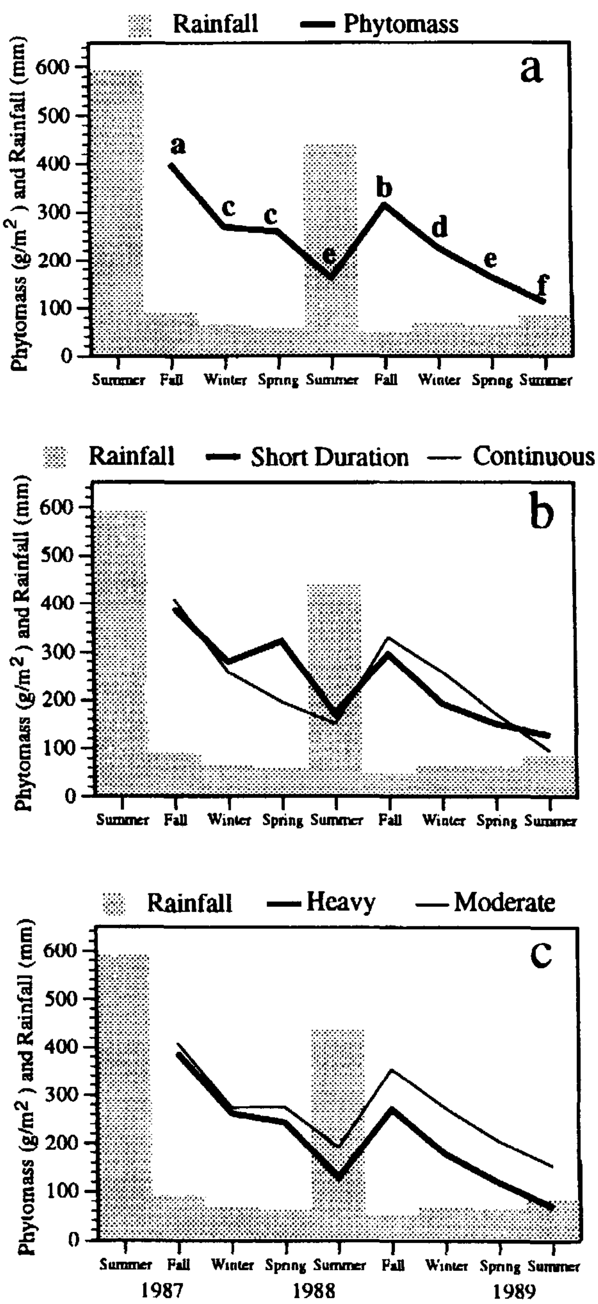

Fig. 2. (a) Seasonal variation ($P < 0.05$) in total phytomass (g/m^2) and seasonal rainfall (mm), means with the same letter among seasons are not significantly different ($P > 0.05$); (b) across grazing systems, and (c) across stocking rates. Welder Wildlife Refuge, San Patricio Co., Texas, 1986–1989.

was 28, 39, and 28% greater under moderate than under heavy stocking rate (Table 3).

Differences ($P < 0.05$) among seasons were detected for all forage classes. Two peaks were detected ($P < 0.05$) for total phytomass, both of them during fall seasons (Fig. 2a). These 2 peaks were preceded by summer rainfall that exceeded 400 mm. Total phytomass declined by approximately 60% from the beginning to the end of the study across all treatments (Fig. 2).

Total phytomass was similar under both grazing systems (Fig. 2b). An exception was spring 1988, in which total phytomass was 39% greater under short-duration grazing than under continuous grazing. This resulted in a significant interaction ($P < 0.05$) between grazing systems and season, especially during spring 1988 and summer 1989. Evidently, the combination of 60 mm of rain during March and April 1988 and 80 mm during May and June 1989 (Fig. 2b), and the rest periods of short-duration grazing contributed to increased grass biomass. In general, total phytomass declined from the beginning of the study to the end, by 77% under continuous grazing and by 67% under short-duration grazing.

Moderate stocking rate had consistently greater phytomass than heavy stocking rate (Fig. 2c). During fall 1987, and winter 1987–1988, differences in total phytomass between stocking rates were small (about 5%). As time progressed, these differences increased up to 55% in favor of the moderate stocking rate. From the first period of evaluation to the last, total phytomass declined by 82% under heavy and by 62% under moderate, suggesting that even at moderate stocking rates, total phytomass can be negatively impacted when moisture is inadequate (Fig. 2c).

Phytomass of preferred forbs changed significantly ($P < 0.05$) among seasons (Fig. 3); significant ($P < 0.05$) peaks were observed during the fall of both years. Preferred forbs declined from fall to summer, a trend more noticeable during the second year, when phytomass declined by 90%, regardless of grazing strategy.

Phytomass of preferred forbs fluctuated under both grazing systems and stocking rates (Fig. 4a). This forage class was most affected by the lack of soil moisture regardless of the grazing

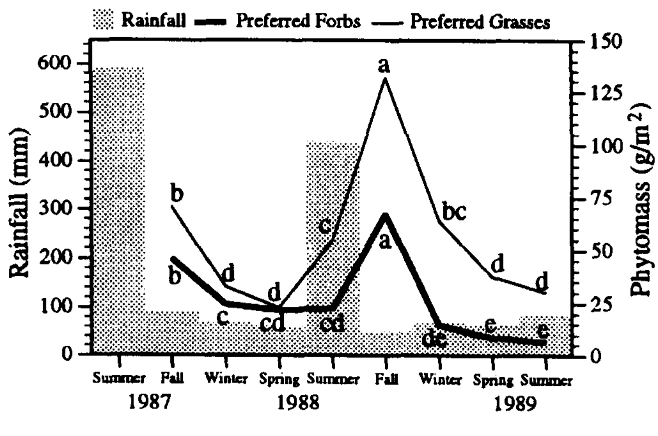

Fig. 3. Seasonal variation ($P < 0.05$) of preferred forbs and grasses (g/m^2) across grazing treatments and seasonal rainfall (mm). Means with the same letter among seasons for preferred forbs and preferred grasses are not significantly different ($P > 0.05$). Welder Wildlife Refuge, San Patricio Co., Texas, 1986–1989.

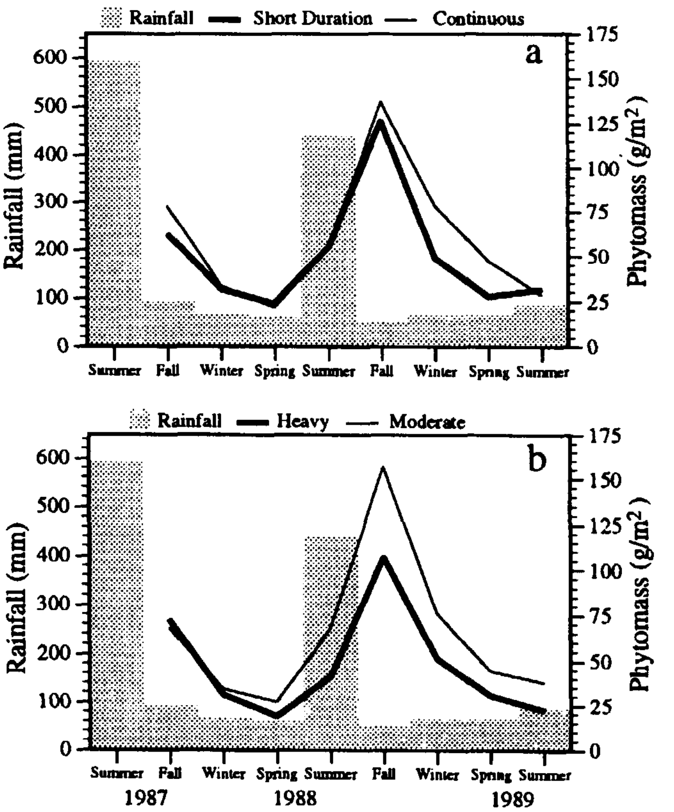

Fig. 4. Seasonal variation of preferred forbs (a) across grazing systems, and (b) across stocking rates, and seasonal rainfall (mm). Welder Wildlife Refuge, San Patricio Co., Texas, 1986–1989.

practice. Phytomass values reached a low of 6 g/m^2 during summer 1989. Phytomass of preferred forbs was slightly greater under continuous grazing, particularly during fall (Fig. 4a).

Phytomass of non-preferred forbs was extremely high during fall 1987, because of the high precipitation during May and June 1987. Portions of the pastures flooded and promoted tremendous growth of sumpweed. After that, non-preferred forbs did not contribute significantly to total phytomass.

Availability of preferred grasses declined by 67% from fall 1987 to spring 1988 and increased by 58% from spring 1988 to summer 1988 as a result of the presence of cool-season grasses, mostly Texas wintergrass. In 1989, phytomass of preferred grasses did not increase in spring because moisture was insufficient to promote growth of cool-season grasses. Phytomass of preferred grasses declined consistently during 1989, resulting in a 77% reduction from fall 1988 through summer 1989.

Phytomass of preferred grasses followed a similar trend as preferred forbs through all seasons under both grazing systems and both stocking rates (Fig. 5). Phytomass of preferred grasses increased in fall after summer precipitation. The seasonal trend on both grazing systems was similar; however, preferred grass phytomass was greater under continuous grazing than under short-duration grazing. Preferred grass phytomass declined by 63% under continuous grazing and by only 48% under short-duration grazing from the first sampling period to the last. The periodic resting of the short-duration grazing pastures may explain such differences. Preferred grass phytomass was as much as 40% greater under the moderate than heavy stocking rate.

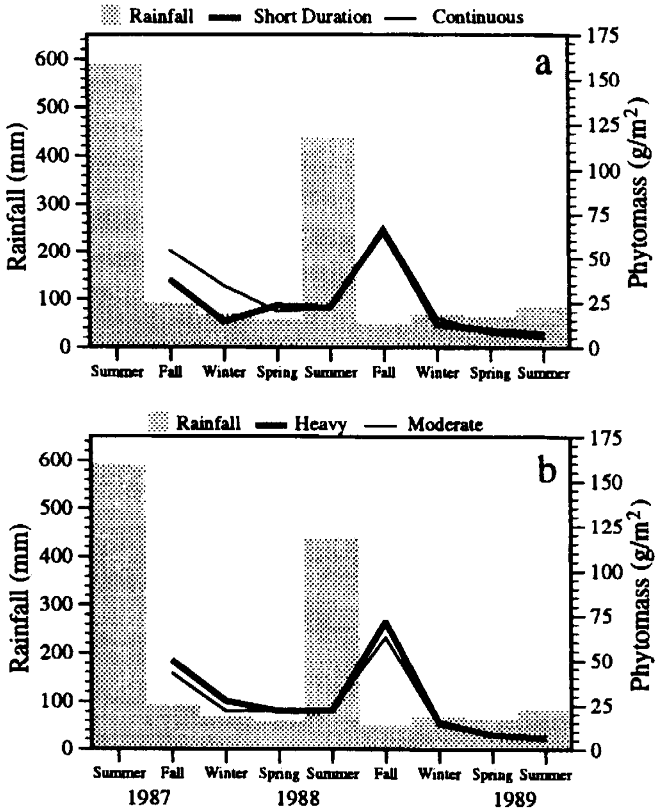

Fig. 5. Seasonal variation of preferred grasses (a) across grazing systems, and (b) across stocking rates, and seasonal rainfall (mm). Welder Wildlife Refuge, San Patricio Co., Texas, 1986–1989.

Litter phytomass changed significantly ($P < 0.05$) across grazing systems and stocking rates. In general, litter peaked when plant species were mature (spring 1988 = 190 g/m^2; winter 1988 = 190 g/m^2; winter 1989 = 140 g/m^2). Moreover, litter was lowest when moisture was not available to promote plant growth (summer 1988 = 79 g/m^2; summer 1989 = 74 g/m^2).

These results confirmed the findings of several studies (Kothmann et al. 1978; Heitschmidt et al. 1986; Ralphs et al. 1990) that stocking rates, particularly heavy rates, have a more significant impact on phytomass than grazing systems. Furthermore, precipitation proved to be the determining factor in the seasonal dynamics of phytomass of the various forage classes. Hart et al. (1988) stated that yearly differences in forage production were largely a result of the amount and distribution of precipitation. However, the combination of heavy stocking rates and low, erratic precipitation could have a more negative impact on the availability of plant species that are important for both wildlife and livestock, especially for white-tailed deer, during critical summer and fall periods.

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