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Seasonal cattle management in 3 to 5 year old bitterbrush stands

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Abstract

Because of its high palatability and sustained levels of forage quality, antelope bitterbrush (*Purshia tridentata* Pursh DC) is one of the most desired shrubs on western U.S. rangelands. Bitterbrush has decreased in abundance in many areas, and efforts to foster its restoration have met with limited success. Because little information is available regarding the grazing management of newly established stands of bitterbrush, this study was undertaken to: 1) determine the effects of early and late-season cattle grazing on bitterbrush, 2) determine when cattle were most likely to forage on these shrubs, and 3) relate use of shrubs to the quantity, quality, and phenology of accompanying herbaceous forages. Ungrazed (control), early-grazed, and dormant-grazed paddocks supporting 3+ year old bitterbrush (randomized complete block design, N = 3) were monitored for 3 years to accomplish this task. When grasses were green and growing, cattle grazed about 6% of the shrubs per day. When grasses and forbs were dormant, about 13% of the shrubs were grazed each day. Rates of use of shrubs were not significantly ($P > 0.05$) correlated with amounts of accompanying herbage available ($r^2 = 0.40$), levels of forage utilization ($r^2 = 0.00$), stocking pressure ($r^2 = 0.00$), crude protein ($r^2 = 0.02$) or neutral detergent fiber content ($r^2 = 0.59$) of accompanying forages, or digestibility of the forages as measured by in-vitro organic matter disappearance (IVOMD) ($r^2 = 0.62$). In stepwise regression analyses Julian date alone accounted for 92% of the variation in rates of use of shrubs and the addition of IVOMD accounted for 98% of the variation. This suggested that bitterbrush was grazed more heavily as the growing season advanced and forage quality of the grasses declined. Shrub height, diameter, and volume were reduced by early grazing in 1 of 3 years when turn out was delayed until grasses were entering anthesis. Cattle grazing when grasses were dormant caused reductions in height, diameter, and volume of the shrubs in all 3 years. Rates of shrub mortality were unaffected by treatment. Bitterbrush in all treatments experienced significant reductions in height, diameter, and volume from wildlife use during the winters of 1993 and 1994 but not 1995. When trials were terminated, shrubs in early-grazed paddocks exceeded ($P < 0.10$) their counterparts in the dormant grazed paddocks in height, diameter, and volume.

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ResumenE

Debido a su alta palatabilidad y niveles sostenidos de calidad de forraje, el “Antelope Bitterbrush” (Purshia *tridentata* Pursh DC) es uno de los arbustos más deseados en los pastizales del oeste de U.S.A. La abundancia de “Bitterbrush” ha decrecido en muchas áreas y los esfuerzos para fomentar su restauración se han cumplido con éxito limitado. Este estudio fue motivado por la poca información disponible acerca del manejo del apacentamiento de poblaciones de “Bitterbrush “ de reciente establecimiento. Este estudio se llevó a cabo para: 1) determinar los efectos que el apacentamiento de ganado, a inicio y fin de la estación, tiene sobre el “Bitterbrush”, 2) determinar cuando es más probable que el ganado forrajee en estos arbustos y 3) realcionar el uso de los arbustos con la calidad, cantidad y fenología de los forrajes herbáceos que crecen en compañia de los arbustos. Durante 3 años se monitorearon potreros sin apacentar (control), apacentados a inicios de estación y apacentados durante la dormancia y que tenian plantas de “Bitterbrush” de más de 3 años de edad (diseño experimental bloques completos al azar, N=3). Cuando los zacates y hierbas estaban verdes y en crecimiento, el ganado apacentó aproximadamente el 6% de los arbustos por día y cuando estaban dormates alrededor del 13%. No hubo correlación significativa ($P > 0.05$) entre las tasa de uso de los arbustos y las cantidades disponibles de forraje herbáceo acompañante ($r^2 = 0.040$), niveles de utilización del forraje ($r^2 = 0.000$), presión de carga animal ($r^2 = 0.000$), proteína cruda ($r^2 = 0.020$) o contenido de fibra neutro detergente ($r^2 = 0.059$) de los forrajes acompañantes o la digestibilidad de los forrajes medida como la desaparición in vitro de la materia orgánica (IVOMD) ($r^2 = 0.062$). En el análisis de regresión, la fecha juliana contribuyó con el 92% de la variación en las tasas de uso de arbustos y la adición de la (IVOMD) explicó el 98% de la variación. Esto sugiere que el “Bitterbrush” fue pastoreado más intensamente conforme la estación de crecimiento avanzó y la calidad de forraje de los pastos declinó. La altura, diámetro y volúmen de los arbustos fueron reducidos por el apacentamiento a inicios de la estación en 1de 3 años cuando el regreso fue retrazado hasta que los zacates estaban entrando en la antésis. En los 3 años, el apacentamiento de ganado cuando los pastos estaban dormantes causó una reducción en la altura, diámetro y volúmen de los arbustos. Las tasas de mortalidad de los arbustos no fueron afectadas por los tratamientos. Las plantas de “Bitterbrush” de todos los tratamientos experimentaron

Shrubs in early-treatments also exceeded ungrazed controls in diameter and volume. Early grazing of pastures either reduced competition or directly stimulated twig growth of the bitterbrush. If managers wish to conserve critical browse for wintering wildlife or enhance development of young bitterbrush, we suggest that pastures be grazed before the most prominent grasses reach anthesis. After grasses have cured, rates of use on bitterbrush by cattle may be 2 to 3 times higher than when accompanying forages were succulent and growing.

Key Words: P*urshia tridentata*, shrub, livestock, big game, winter range, wildlife, habitat

ficativas de altura, diámetro y volúmen por el uso de la fauna silvestre durante los inviernos de 1993 y 1994, pero no el de 1995. Cuando los ensayos terminaron, los arbustos de los potreros apacentados a inicio de estación excedieron (P < 0.01) en altura, diámetro y volúmen a sus contrapartes de los potreros apacentados en la época de dormancia. Los arbustos pastoreados a inicio de estación también excedieron en diámetro y volúmen a los tratamientos control. El apacentamiento de los potreros a inicios de la estación reduce la competencia o estimula directamente el crecimiento de las yemas de "Bitterbrush". Si los manejadores desean conservar el forraje del "Bitterbrush" para alimento de la fauna silvestre en el invierno o aumentar el desarrollo de plantas jovenes sugerimos que los potreros sean apacentados antes de que los zacates más importantes alcancen la antésis. Después de que los zacates han madurado, la tasa de uso del "Bitterbrush" por ganado puede ser de 2 a 3 veces mayor que cuando los forrajes acompañantes estan suculentos y en crecimiento.

Antelope bitterbrush (*Purshia tridentata* Pursh DC) is one of several shrubs important to mule deer (*Odocoileus hemionus hemionus*), pronghorn (*Antilocarpa americana*), and livestock on rangelands in western North America (Kufeld et al. 1973, Vavra and Sneva 1978, Neal 1981, Urness 1981). It occurs in several vegetation types on about 140 million hectares (Hormay 1943) from British Columbia to California and east into Montana and New Mexico. Because crude protein content of bitterbrush typically remains above 8.0% year-around (Hickman 1975, Kituku et al. 1992), it can substantially enhance the late-season diet quality of ruminants when nutritive value of herbaceous forages has declined to sub-maintenance levels (Raleigh and Lesperance 1972). For these reasons bitterbrush is deemed especially valuable on big game winter ranges.

Senescence, wildfires, excessive herbivory, and low recruitment, have decreased bitterbrush abundance in many areas (Billings 1952, Tueller and Tower 1979, Winward and Alderfer-Findley 1983), and efforts to foster its restoration have most often met with limited success (Hubbard 1964, Kituku et al. 1995). Hubbard (1957) and Dealy (1970) demonstrated that competing vegetation can significantly reduce establishment and subsequent stature of bitterbrush seedlings, and plants must reach an age of 60 to 75 years before maximum annual yield is realized (McConnel and Smith 1977). In vegetation management programs, burning typically results in greater mortality of bitterbrush than does clipping or rotobeating (Mueggler and Blaisdell 1958, Clark et al. 1982). Heavy grazing may also reduce plant longevity (McConnel and Smith 1977). While young transplants appear to benefit from grazing protection (Dealy 1970, Ferguson 1968), established bitterbrush generally responds well to defoliation, and grazed plants produce more and longer twigs than ungrazed controls (Tueller and Tower 1979, Billbrough and Richards 1993, Kituku et al. 1994). This stimulation of twig development may not occur on less productive sites, and in some years annual production of twigs may also be affected by extremely low temperatures (Jensen and Urness 1979) and fluctuations in annual precipitation (Garrison 1953, Kindschy 1982.).

Most bitterbrush research has focused on well-established shrubs or first-year transplants, and there is little information on grazing management applicable to newly established stands of bitterbrush. The objectives of this research were: 1) to determine the effects of early and late-season cattle grazing on the subsequent growth and survival of young bitterbrush plants; 2) determine the periods within a grazing season when cattle were most likely to forage on young shrubs; and 3) to determine if use of bitterbrush by cattle is related to quantity, quality, and phenology of the accompanying herbaceous forage. This was accomplished in a 3-year study by monitoring rates of utilization, survival, and stature of young bitterbrush in seasonally grazed and ungrazed paddocks.

Methods

Site history and description

In 1990, wildfire charred about 30,000 ha of Bureau of Land Management (BLM), United States Forest Service, and deeded property north and west of Burns, Ore. Much of the area consisted of pine-forest/sagebrush-steppe-transition range which had historically been grazed by cattle and was important for wintering mule deer and elk (*Cervus elaphus nelsoni*). Revegetation efforts began immediately, and BLM properties were seeded with 'Secar' Snake River wheatgrass (*Elymus lanceolatus* (Scribner & J.G. Smith) Gould) at 9 kg/ha^{-1}, and in areas where it had previously existed, antelope bitterbrush was included at a rate of 2.2 kg/ha^{-1}. The bitterbrush seed was acquired commercially, but its collection locale was unknown.

Soil in the area (43°37'N 119°24'W, elevation 1,584 m) was a fine, montmorillonitic, frigid Typic Argixeroll. Vegetation prior to the fire included a scattered overstory dominated by western juniper (*Juniperus occidentalis* Hook.), a shrub layer characterized by mountain big sagebrush (*Artemisia tridentata* subspp. vaseyana (Rydb.)Beetle) with a minor bitterbrush component, and herbaceous vegetation dominated by bluebunch wheatgrass (*Agropyron spica-*

tum (Pursh)Scribn. & Smith) and bottlebrush squirreltail (*Sitanion hystrix* (Nutt.)Smith).

In the absence of competing woody vegetation, surviving herbaceous plants and emerging seedlings responded well in the growing seasons after the fire. Bureau of Land Management samplings detected 8,450 bitterbrush seedlings ha^{-1} in 1991 and 3,410 ha^{-1} in 1992. Crop-year precipitation (September— June), which is highly correlated with annual forage production in the region (Sneva 1982), was 91 and 86% of the long term mean (255 mm, n = 40) for the 1991 and 1992 growing seasons, respectively (NOAA 1990–1995, Squaw Butte Station, 43°29'N 119°43'W). In accordance with BLM policy, livestock grazing was not allowed in 1991 and 1992 to aid recovery of vegetation, and the charred remains of small trees and shrubs provided the only evidence of the fire after 2 growing seasons.

Pasture establishment and grazing schedules

Nine experimental pastures (1.47 ha each) were established in the reclaimed area the fall of 1992. Study design was a randomized complete block with 3 replications. Treatments included: 1) pastures grazed by cattle when grasses were green and growing (early), 2) pastures grazed after herbaceous forages had ceased growth and become dormant, and a third which was not grazed by cattle (control) but was accessible to wintering deer, elk, and pronghorn. Because of wet conditions in the spring of 1993, we could not get cattle to the paddocks as early as intended, and turn-out occurred when grasses were entering anthesis. Treatments were not re-randomized among pastures each year, so results reflect the cumulative effect of treatments over the 3 years. Pastures were stocked at varying rates, depending on levels of forage available each year and stock on hand. Cattle were Hereford X Angus crosses with 3 yearling bulls in each pasture in 1993, 2 cow/calf pairs in 1994, and 2 yearling steers in 1995.

Sampling protocol

Permanent end-points of 91-m line-transects were marked with metal stakes in each pasture. The positions along a transect and distances left or right of the tape were recorded for 25 randomly selected bitterbrush in each pasture. During the study, any shrub lost to grazing or mortality was substituted for by the nearest available neighbor. Prior to each grazing trial, the dimensions (greatest diameter and height) of each shrub were measured in control and treatment paddocks, and the tips of any recently defoliated twigs were marked with black ink to facilitate detection of subsequent browsing. A measure of available herbage was obtained by clipping 20-25, 1-m^2 plots from pastures to be grazed. Perennial grasses were sorted by species, and forbs were composited. After oven drying (40°C) and weighing, grasses were composited, thoroughly mixed, and grab samples of grasses and forbs obtained for subsequent grinding and assays of forage quality. Forage analyses included crude protein (CP) with AOAC (1980) procedures, neutral detergent fiber (NDF) following Goering and Van Soest (1970), and in-vitro organic matter disappearance (IVOMD) to index digestibility (Tilley and Terry 1963).

During grazing trials, technicians returned every 2 days, relocated each designated shrub in treatment and control pastures, and noted presence or absence of any new signs of defoliation. Livestock grazing continued until approximately 40% of the accompanying forage had been utilized or 80% or more of the shrubs exhibited some sign of utilization. After cattle were removed, available herbage was resampled by clipping 20 to 25, 1-m^2 plots to estimate levels of forage utilization, and the greatest diameter and height of each shrub was recorded to facilitate before and after comparisons of grazing effects on bitterbrush stature.

A paddock served as the basic experimental unit in this study and measures of bitterbrush or herbage production were totaled across subsamples within pastures for analyses. Following analyses, data were converted to per plant or unit $area^{-1}$ formats for presentation.

Statistical procedures

Linear regression was used to relate the cumulative number of shrubs utilized (dependent variable) with the corresponding number of days (n = 9–21) the 3 paddocks had been grazed (independent variable) for each of the 6 seasonal grazing trials. Regressions were forced through origin in these analyses, so the slopes depict the relative rates of defoliation (shrubs day^{-1}) that bitterbrush experienced. The slopes of these linear equations were compared among grazing treatments and years using the procedures of Snedecor and Cochran (1967). Rates of bitterbrush utilization for the 6 seasonal trials (dependent variable, were regressed against forage availability, percent of forage utilized, stocking pressure, forage quality of the associated grasses (CP, NDF, and IVOMD), and the beginning Julian date for each trial in an effort to detect consistent predictors of bitterbrush utilization by cattle. Statistical significance in linear and multiple regression analyses was assumed at $P \leq 0.05$.

We made an assumption the shrubs were cylindrical in shape, and integrated our measures of height and diameter to derive canopy-volume (liters). For our height, diameter, and volume variables, t-tests (4 df) were used for comparisons among treatments on a given date, and paired t-tests (2 df) were used for comparisons within a treatment between adjacent dates. Because the dimensions of our shrubs were quite variable, statistical significance was assumed at $P \leq 0.10$ for all t-tests. Shrub mortality, compiled over the duration of the trials, was summarized with a randomized complete block analysis of variance, and statistical significance was assumed at $P \leq 0.05$. To provide a brief description of accompanying vegetation on the area we sampled the frequency and density of prominent perennial grasses and shrubs at the close of the 1995 growing season in fifty 1-m^2 plots per paddock.

Results

Crop-year precipitation in the area was 167, 56, and 143% of average (255 mm) for the 1993, 1994, and 1995 growing seasons, respectively,

Table 1. Phenology of associated grasses, available forage (±SE), stocking rates, percent of forage utilized (±SE), and indices of forage quality of associated grasses (CP and NDF(±SE)) in trials evaluating the seasonal effects of cattle grazing on young bitterbrush plants near Burns, Ore.

	Phenology of grasses					
	Anthesis 1993	Dormancy 1993	Vegetative 1994	Dormancy 1994	Late-boot 1995	Dormancy 1995
	Available forage					
	Kg ha^{-1-}					
Grasses	718±155	742±25	549±76	605±14	540±35	693±89
Forbs	201±46	111±57	74±13	49±13	191±41	48±9
Total	919±112	853±30	623±63	654±10	731±76	
Stocking rate	Aum ha^{-1}					
	0.83	0.41	0.37	0.37	0.64	0.37
	Forage Utilization					
--	Percent (%) of standing crop					
Grasses	26±15	40±4	38±6	33±4	19±8	22±9
Forbs	56±14	64±2	50±9	77±11	71±3	36±14
Total	37±13	43±6	40±10	36±7	32±15	23±14
	Quality of grasses					
--	Percent (%) dry weight					
CP	6.9±0.3	5.2±0.7	8.6±0.6	4.3±0.2	12.7±0.2	4.6±0.3
NDF	63±0.4	70±1.1	67±1.1	71±1.6	45.3±1.5	37±0.9

and it is noteworthy that this included the wettest and driest years on record for the region. This variability affected herbage production, which ranged from a low of 623 to a high of 919 kg ha^{-1} (Table 1). Densities and frequencies of the most prominent grasses and shrubs in the pastures are found in Table 2.

Rates of Utilization

Rates of bitterbrush utilization by cattle varied among years and grazing seasons (Fig. 1). For 2 of the 6 regressions (Fig. 1A and 1D) a quadratic model would have provided a slightly better fit of the data, but we employed a linear function so the slopes could be interpreted as number of shrubs grazed per day. Each year the heaviest use of shrubs occurred when the grasses were dormant and bitterbrush and late maturing forbs provided the only succulent forage. Mean rate of use during dormant trials was 3.24 plants browsed day^{-1} and ranged between 4.40 and 1.86 plants day^{-1} (Fig. 1). We ended each of the 3 dormant trials sooner than intended because nearly all of the shrubs had been grazed after only 6 to 8 days. When associated herbaceous vegetation was green and growing, our heaviest use on bitterbrush (x = 1.56 plants day^{-1}) occurred in 1993 when the grasses were in anthesis. This trial was also ended because nearly all shrubs were browsed after the pastures had been grazed for 12 days. When grasses were not headed out and furnished only leafy material (vegetative 1994 and late-boot 1995), rate of use on bitterbrush averaged only 0.39 plants day^{-1}.

With linear regressions, rates of use on bitterbrush were not significantly ($P > 0.05$) correlated with amounts of herbage available ($r^2 = 0.40$), levels of forage utilization ($r^2 = 0.007$), stocking pressure ($r^2 = 0.000$), or indices of forage quality for the accompanying grasses (CP $r^2 = 0.02$; NDF $r^2 = 0.59$; and IVOMD $r^2 = 0.62$). Rates of use on bitterbrush were correlated ($P < 0.01$) with the Julian date for the beginning of each trial with the equation being: plants grazed day^{-1} = 0.026*Julian date -3.05 ($^2 = 0.92$). In stepwise regression analyses, the combination of Julian date and IVOMD accounted for 98% of the variability in rates of use on the shrubs. The equation was: plants grazed day^{-1} = 0.020*Julian date + 0.205*IVOMD - 11.4. Crude protein (CP) was the first non-significant variable ($P = 0.19$) to enter the model when analyses were terminated.

Table 2. Mean density (plants m^{-2})and frequency m^{-2} (±SE) of the most prominent grasses and shrubs occurring on reseeded forest/sagebrush-steppe transition range near Burns, Ore. 5 years after a wildfire.

Species	Density Plants m^{-2}	Frequency Percent (%)
Grasses		
Poa sandbergii Vasey	4.5 ±0.4	80 ±3.7
Agropyron spicatum (Pursh) Scribn. & Smith	1.4 ±0.2	58 ±4.3
Sitanion hystrix (Nutt.) Smith	1.3 ±0.2	53 ±6.2
Stipa thurberiana Piper	0.6 ±0.2	28 ±7.7
Festuca idahoensis Elmer	0.5 ±0.1	29 ±3.3
Koeleria cristata Pers.	0.5 ±0.1	27 ±4.6
Agropyron intermedium (Host) Beauv.	0.1 ±0.0	3 ±1.5
Shrubs		
Purshia tridentata Pursh DC	0.3 ±0.1	21.1 ±2.3
Artemisia tridentata subspp. *vaseyana* (Rydb.)Beetle	0.3 ±0.1	17.2 ±4.1
Chrysothamnus viscidiflorus (Hook.) Nutt.	0.2 ±0.1	14.0 ±3.9
Tetradymia canescens DC.	--[1]	1.7 ±0.9
Ribes cereum Dougl.	0.9 ±0.7	

[1]Density <0.1 m^{-2}

Heights of Shrubs

Effects of grazing treatments on shrub height are found in Table 3. In 1993 both early- (10 June–24 June) and dormant- (20 September–26 September) treatments reduced shrub height by 5 to 6 cm ($P < 0.02$) relative to controls. Shrubs in the early-grazed pastures exhibited significant (P= 0.06) growth after grazing (2.7 cm), but not enough to overcome an early vs. control difference when plants were measured on 26 September 1993. Overwinter (1993–94) use by wildlife erased treatment:control differences when shrubs were first measured on 5 May 1994. In 1994, only the dormant-grazing trial (8 August–18 August) reduced bitterbrush height (–3.7 cm, P = 0.07). Overwinter (1994–95) use by wildlife affected heights of bitterbrush

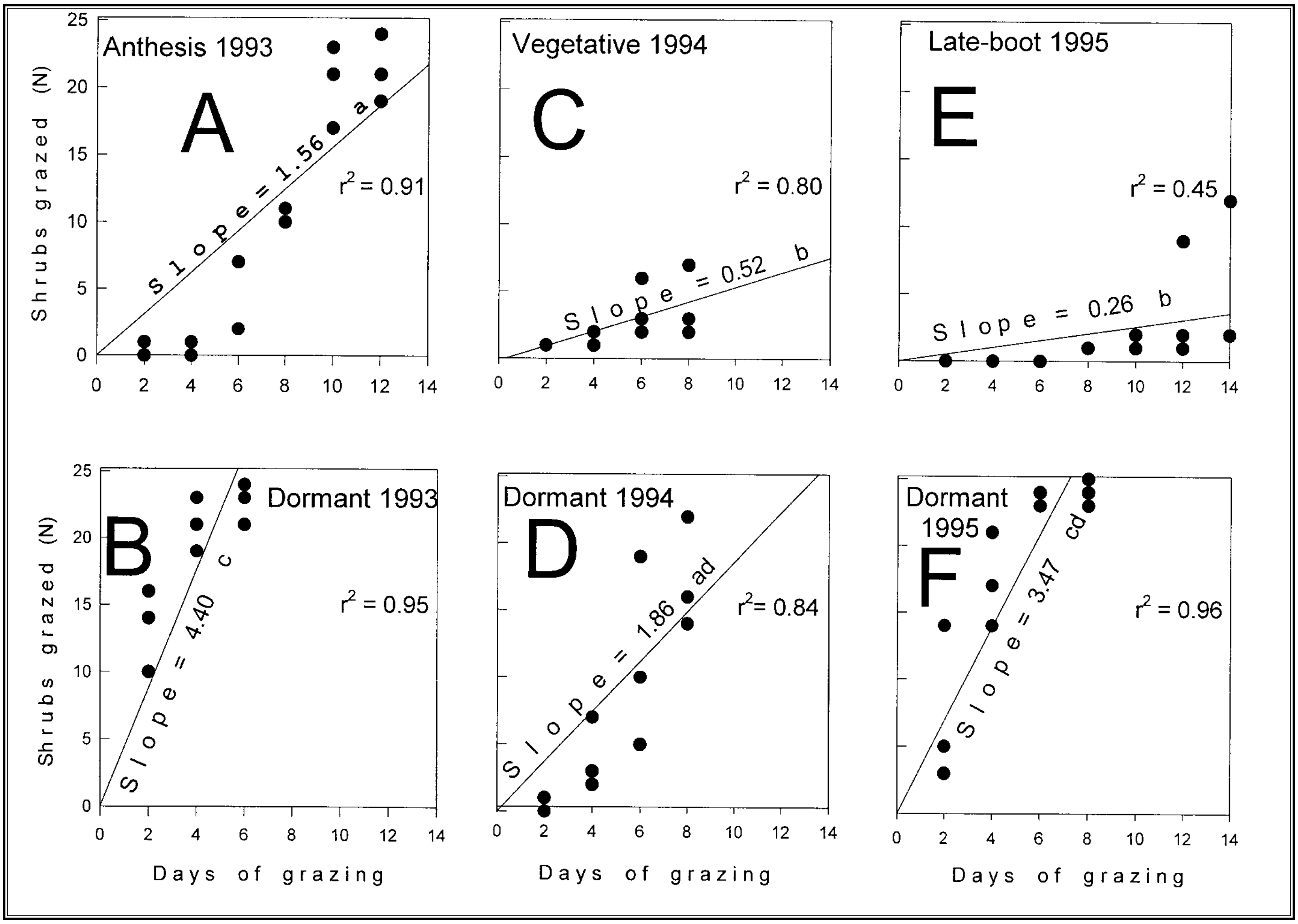

Fig. 1. Rate (shrubs d-1) at which young bitterbrush were grazed by cattle on forest/sagebrush-steppe rangelands near Burns, Ore. in seasonal grazing trials. Phenology indicators reference the growth stage of associated perennial grasses. The slope of lines sharing a common letter do not differ significantly (P<0.05).

in all treatments, erasing a significant early-grazing vs. dormant-grazing difference, but not a control vs. dormant grazing disparity (P = 0.05). Early grazing in 1995, when grasses were in the late-boot stage of phenology, had no effect on shrub height, and substantial growth among all treatments again erased significant differences among treatments by late-summer (22 August 95) when shrubs were approximately 26 cm tall (P > 0.10). The final dormant-season trial in 1995 (22 August through 30 August) produced a reduction (P = 0.10) in heights of shrubs relative to early-grazing and control treatments. Treatment differences sustained themselves over the subsequent winter despite significant use by wildlife of shrubs in the early-grazed pastures (P = 0.04).

Diameters of Shrubs

The diameters of bitterbrush were similarly affected by our treatments (Table 4). When trials began (10 June 1993), shrubs in our early grazed pastures were greater in diameter ($\overline{x}$ = 3.7 cm) than the controls (P = 0.02), but cattle grazing when grasses were in anthesis eliminated this difference. In 1994 and 1995 the diameters of shrubs in the early grazed pastures were unaffected by grazing. In general, they significantly (P < 0.10) exceeded the controls in diameter. Dormant season grazing by cattle in all 3 years caused (P < 0.04) reductions in shrub diameters, but dormant vs. control differences were significant (P < 0.03) for only 2 of those years (1993 and 1995). Significant (P < 0.07) overwinter use of all treatments by wildlife occurred in 1993 and 1994 but not in 1995.

Volumes of Bitterbrush Canopies

The mean volume of shrubs increased from approximately 2 to 38 liters during the trials (Table 5), with the most substantial increases occurring in the 1995 growing season. Early grazing by cattle reduced volume (P = 0.04) in the June 1993 trials but had no effect in 1994 or 1995. Late grazing reduced volumes (P < 0.07) in all 3 years. Early, dormant, and control treatments were all reduced (P < 0.10) in volume by overwinter utilization in 1993 and 1994. Only the shrubs in the early-grazed pastures decreased in volume over the winter of 1995–96 (P = 0.05).

Among treatments, early grazing caused a reduction (P = 0.07) in the volume of shrubs relative to controls in 1993, but had no effect in 1994. Bitterbrush in the early-grazed paddocks exceeded controls by 15 to 19

Table 3. Mean height of bitterbrush in seasonally grazed and control paddocks in a forest/sagebrush-steppe ecotone near Burns, Ore. Cattle grazed paddocks when grasses were green and growing (early) or when grasses had cured (dormant) each year.

	Grazing treatment		
Sampling Date	Control	Early	Dormant
	cm ± SE		
10 Jun 93	13.9±1.0a[1]A[2]	13.8±0.6aA[3]	--[4]
24 Jun 93	14.8±1.3aB	8.6±1.3bB	--
20 Sep 93	19.9±1.8bC	11.4±1.9aC	16.0±1.2abA
26 Sep 93	16.2±1.2bC	11.4±1.9aC	9.7±0.9aB
27 Apr 94	12.5±2.3aD	9.6±2.1aD	9.2±0.7aB
5 May 94	12.8±2.2aD	8.9±1.5aD	9.2±0.7aB
8 Aug 94	16.4±2.4aE	15.1±1.4aE	14.2±1.3aC
16 Aug 94	16.0±2.3aF	15.1±1.3aE	10.5±0.9bD
27 Apr 95	15.6±1.8aG	13.3±1.1abF	8.5±0.7bE
8 Jun 95	15.1±2.5aG	14.4±0.6aF	--
22 Aug 95	26.8±2.3aH	28.6±1.3aG	23.3±01.5aF
30 Aug 95	26.2±2.2aI	28.6±1.3aG	11.2±0.8bG
3 May 96	23.9±3.3aI	25.0±1.4aH	10.7±0.6bG
19 Aug 96	29.2±2.8aJ	32.9±1.2aI	20.1±0.9bH

[1]Means within a row sharing a common lower case letter are not significantly different (P>0.10).
[2]Adjacent means within a column sharing a common upper case letter are not significantly different (P>0.10).
[3]Shaded pairs of values in columns denote mean heights of shrubs before (top) and immediately after (bottom) a grazing treatment.

Table 4. Mean diameter of bitterbrush in seasonally grazed and control paddocks in a forest/sagebrush-steppe ecotone near Burns, Ore. Cattle grazed paddocks when grasses were green and growing (early) or when grasses had cured (dormant) each year.

	Grazing treatment		
Sampling Date	Control	Early	Dormant
	cm ± SE		
10 Jun 93	12.6±0.8a[1]A[2]	16.3±0.5ba[3]	–-[4]
24 Jun 93	14.1±1.3aB	11.8±0.6aB	--
20 Sep 93	18.5±1.7aC	18.7±1.8aC	20.1±1.6aA
26 Sep 93	17.6±1.2aC	18.7±1.8aC	12.8±0.9bB
27 Apr 94	13.3±1.0aD	13.8±1.3aD	11.5±1.1aC
5 May 94	12.3±1.1aD	13.8±1.3aD	11.5±1.1aC
8 Aug 94	19.2±2.2aE	13.4±1.1aD	19.9±1.3bF
16 Aug 94	18.7±2.1aE	24.8±1.1bE	15.1±1.0aE
27 Apr 95	15.1±2.6aF	20.9±0.8bF	11.9±1.0aF
8 Jun 95	18.1±2.7aG	23.7±0.9aG	--
22 Aug 95	30.2±3.6aH	41.2±5.4bH	29.9±1.5aG
30 Aug 95	30.1±3.3aH	41.2±5.4bH	18.4±0.4cH
3 May 96	28.1±2.9aH	38.9±3.1bH	17.6±0.5cH
19 Aug 96	36.0±2.8aI	46.3±2.9bI	29.1±2.1aI

[1]Means within a row sharing a common lower case letter are not significantly different (P>0.10.
[2]Adjacent means within a column sharing a common upper case letter are not significantly different (P>0.10).
[3]Shaded pairs of values in columns denote mean diameters before (top) and immediately after (bottom) grazing treatments.
[4]Not sampled

liters with the late 1995 and early 1996 measures ($P < 0.10$). After grazing, shrubs in the dormant treatment were of lesser volume ($P < 0.05$) than controls on 26 September 1993 and 30 August 1995, but differences were not significant in 1994. Shrubs in the early-grazed pastures were greater in volume than those in dormant pastures on 26 September 1993 and on every date sampled after 8 August 1994 ($P < 0.01$).

The multiplicative effect of integrating shrub height and diameter in our expressions of volume were quite striking and greatly enhanced disparities among treatments, particularly near the end of our trials. When shrubs were last measured (19 August 1996), mean heights and diameters of the early and dormant treatments exhibited about a 2.3 fold difference. This was amplified to an 11 fold difference (30.4 vs. 2.7 liters), however, when height and diameter were combined in an expression of volume.

Mortality of Shrubs

Total mortality of the bitterbrush in early, control, and dormant grazed pastures averaged 14, 10, and 24%, respectively, for the duration of the project. Variability was high, however, and no treatment effects were recognized for mortality or densities of bitterbrush ($\bar{x}$ = 3,160 ha^{-1} SE = 500) when trials were terminated.

Discussion

Previous research suggests that livestock use of mature bitterbrush typically increases as the growing season advances (Lesperance et al. 1970, Stuth and Winward 1977, Neal 1981, Urness 1981), and our results with young plants further support those observations. Neal (1981) reported that use of bitterbrush by cattle peaked in July and then decreased as the grazing season advanced. Cattle used some bitterbrush in all of our trials, but generally rates of use simply increased as the growing season advanced. Neal (1981) suggested that peak use of bitterbrush by cattle occurred when the seeds developed and turned dark. This also coincides with the period of highest moisture content and highest apparent digestibility of bitterbrush (Hickman 1975). Due to their young age, shrubs in our study exhibited no reproductive effort, and we suspect that the seasonal dynamics of animal preference and palatability of all the forages on offer contributed to the selection of bitterbrush by cattle.

Bitterbrush appears quite tolerant of early growing-season browsing, and several aspects of livestock grazing can contribute to the shrubs production and forage value. Removal or reductions in leaf area of competing vegetation have been shown to substantially increase twig lengths and yield of bitterbrush (Garrison 1953, Hubbard 1957, Ferguson and Basile 1966, McConnel and Smith 1977, Neal 1981, Reiner and Urness 1982). These increases in growth have been attributed to greater availability of moisture and nutrients.

Browsing during winter dormancy or early spring also stimulates subsequent twig growth (Garrison 1953, McConnel and Smith 1977, Kituku et al. 1994). This response is related to the removal of apical dominance (Tueller and Tower 1979) and altered resource allocation patterns within the shrubs (Billbrough and Richards 1993). Defoliation can also increase the nitrogen and phosphorus content of twigs and the digestibility of subsequent growth (Kituku et al. 1992).

Long term protection of highly productive bitterbrush sites from grazing can actually lower annual production of twigs by up to 70% (Martinson 1960, Tueller and Tower 1979). Browsing effects, however, may not be as strongly expressed on less productive sites because of their restricted growing season (Garrison 1953, Tueller and Tower 1979, Billbrough and Richards 1993). Twig growth in any particular year may also be affected by available moisture, with up to 40% of annual variation accounted for by crop-year precipitation (Kindschy 1982). Extreme cold can also affect twig production with up to 66% of the current year's live twigs killed in a given year (Jensen and Urness 1979).

With the exception of 1993, shrubs in our early-grazed pastures equaled controls in height at the end of the growing season (Table 3). Diameters of shrubs in the early treatment were similar to controls in late-summer 1993, and exceeded controls in 1994 and 1995 (Table 4). Volumes of shrubs in the early treatment equaled those of controls in late-summer of 1993 and 1994, and then greatly exceeded controls in 1995 (Table 5). With the exception of diameter in 1994, shrubs grazed in our dormant season trials were of lesser height, diameter, and volume than either the control or early-grazed treatments by the end of the growing season. The combination of subsequent winter wildlife use and summer growth erased most of the dormant versus control effects evident in 1994 and 1995. Early versus dormant season grazing differences in diameter persisted through the following 1994 and 1995 growing seasons. Early versus dormant treatment differences in volume persisted through the 1995 growing season.

Table 5. Mean volume of bitterbrush in seasonally grazed and control paddocks in a forest/sagebrush-steppe ecotone near Burns, Ore. Cattle grazed paddocks when grasses were green and growing (early) or when grasses had cured (dormant) each year.

	Grazing treatment		
Sampling Date	Control	Early	Dormant
---------------liters ± SE----------------			
10 Jun 93	1.8±0.3a[1]A[2]	2.9±0.1bA[3]	--[4]
24 Jun 93	2.4±0.6aA	1.0±0.2bB	--
20 Sep 93	4.9±1.1aB	3.4±1.3aB	5.3±1.2aA
26 Sep 93	3.9±0.6aB	3.4±1.3aB	1.3±0.3bB
27 Apr 94	1.8±0.6aC	1.6±0.9ac	1.0±0.2aC
5 May 94	1.8±0.5aC	1.4±0.5aC	1.0±0.2aC
8 Aug 94	4.9±1.4aD	7.4±1.2aD	4.5±1.0aD
16 Aug 94	4.5±1.2abE	7.4±1.2aD	1.9±0.4bE
27 Apr 95	2.7±1.0abE	4.6±0.7aE	1.0±0.3bF
8 Jun 95	4.2±1.4aF	6 .4±0.5aF	--
22 Aug 95	20.0±5.6aG	38.5±5.5bG	15.6±2.1aG
30 Aug 95	19.4±4.9aG	38.5±5.5bH	3.0±0.3cH
3 May 96	15.6±4.0aG	30.4±5.8bI	2.7±0.1cI
19 Aug 96	30.8±6.1aH	56.0±7.5bJ	13.6±2.3cJ

[1]Means within a row sharing a common lower case letter are not significantly different (P>0.10).
[2]Adjacent means within a column sharing a common upper case letter numeral are not significantly different (P>0.10).
[3]Shaded pairs of values in columns denote mean volumes before (top) and immediately after (bottom) grazing treatments.
[4]Not sampled

Because we did not monitor individual twig dynamics, soil moisture, or nutrient availability in this study, we can only speculate on the specific mechanisms that contributed to the eventual early versus control differences in diameter and volume when the shrubs were last measured in 1996 (Tables 4 and 5). Given that shrubs in our early treatment developed a greater diameter than shrubs in control or dormant pastures, we suspect that removal of apical dominance on the shrubs and the reduction in leaf area of competing forages may have interacted to stimulate twig development.

We found very poor correlations between rates of use of shrubs and forage availability, levels of utilization of accompanying herbaceous forages, stocking rate, and indices of forage quality for the associated grasses. Given that levels of forage utilization never exceeded 45% in this project, we suggest that stocking rates or similarly derived expressions of forage utilization are poor predictors of cattle use of bitterbrush at light levels of grazing. This may not be true when heavier utilization of herbaceous forages occurs. Even with our light levels of forage utilization, however, the specific timing of the grazing period had a great influence on whether or not bitterbrush was utilized. The strong correlation between rates of livestock use on bitterbrush with Julian date for the beginning of each trial and IVOMD of the accompanying grasses implied that cattle simply make greater use of bitterbrush as the growing season advances and forages mature.

Conclusions

If a manager's goal is to maximize available browse for wintering wildlife or to foster establishment of a young stand of bitterbrush, we suggest the shrubs be afforded some protection from cattle grazing after the most prominent grasses enter anthesis. Age-yield interactions of bitterbrush, presented by McConnel and Smith (1977), suggest that individual shrubs 10 to 20 years of age can exhibit compensatory growth if grazed in spring or early summer. In our trials, early grazing of pastures increased both diameter and volume of shrubs by their fifth growing season. After grasses cured, the cattle appeared to seek out bitterbrush, and rate of use on the shrubs was 2 to 3 times greater than when accompanying herbaceous forages were succulent and actively growing. Livestock returns may still be realized from bitterbrush sites, however, by grazing cattle before the grasses initiate reproductive efforts and bitterbrush twigs start to elongate. Cattle tend to focus on the herbaceous component at this time, and if bitterbrush twigs are defoliated, there is ample opportunity in most years for regrowth during the remaining portion of the growing season. When managing bitterbrush sites, cattle turn-out should be based on the phenologies of forages instead of specific calendar dates.

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