ADAPTIVE GRAZING MANAGEMENT AND USE OF FORAGE BY CATTLE (*BOS TAURUS*) AND ELK (*CERVUS ELAPHUS*) IN CENTRAL ARIZONA

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Abstract—During March 2001–December 2003, we measured use of forage and height of stubble in pastures at low, middle, and high elevations. In years with higher precipitation, use of forage by cattle (*Bos taurus*) and elk (*Cervus elaphus*) was less in the middle elevation compared to low and high elevations. In the worst drought year on record (2002), use of forage increased with elevation. Overall, use of forage was greater in 2002 than in 2001 and 2003. Shorter stubble corresponded to lower production and higher use of forage. Total use of forage did not exceed 50%.

Resumen—Durante el periodo entre marzo de 2001 y diciembre de 2003, medimos el uso del forraje y la altura del rastrojo en pastizales de elevaciones bajas, medianas y altas. En los años con la precipitación más alta, el uso del forraje por ganado (*Bos taurus*) y elk (*Cervus elaphus*) fue menor en elevaciones intermedias, comparado con el uso en elevaciones bajas y altas. En el año con el record de sequía más severa registrada en la zona (2002), se observó un incremento en el uso del forraje con la elevación. En general, el uso del forraje fue mayor en 2002 que en 2001 y 2003. Los rastrojos más bajos correspondieron a la producción más baja y a un mayor uso del forraje. El uso total del forraje no excedió el 50%.

Adaptive resource management acknowledges uncertainty in ecosystems and the need to monitor systems so that adjustments can be made to management activities to improve or sustain long-term performance (i.e., long-term health of rangeland; Lancia et al., 1996). Specialized grazing systems have been developed in areas where wild and domestic ungulates might compete for forage (Urness, 1982). Specialized grazing systems can improve quantity and quality of forage, and health and body condition of cattle (*Bos taurus*) and elk (*Cervus elaphus*; Anderson and Scherzinger, 1975; Alt et al., 1992; Wisdom and Thomas, 1996; Halstead et al., 2002). Grazing by cattle can be timed so that perennial grasses are grazed more intensively during the vegetative stage when they are more tolerant of herbivory, or during dormancy that can stimulate regrowth when adequate moisture is available in the soil (Vavra and Sheehy, 1996).

In central Arizona, cattle and elk compete for forage, which creates controversy between wildlife biologists, ranchers, and land managers (Torstenson et al., 2002). Grazing-management practices that control number of animals and temporal and spatial distribution of cattle have been implemented in Arizona to attract wildlife to areas grazed by cattle (Halstead et al., 2002). In addition, managers of rangelands use adaptive management to manipulate movements of livestock in response to past and current conditions of forage (Moir and Block, 2001). Our objective was to evaluate the ability of adaptive grazing management to provide forage for cattle and elk at three elevations and associated plant communities, and to stay within guidelines for use of forage and height of stubble imposed by the United States Forest Service. Three elevations were selected because managers of range and wildlife hypothesized that competition for forage was occurring between cattle and elk in these areas.

Materials and Methods—The University of Arizona V Bar V Ranch in Coconino and Yavapai counties provided the opportunity to examine use of forage by elk throughout seasons relative to temporal and spatial use of forage by cattle. The V Bar V Ranch and its Walker Basin allotment are ca. 48 km E Camp Verde on 31,174 ha of grazing land permitted by the United States Forest Service and 17 ha of deeded land. The Walker Basin allotment is 7–8 km wide, separated into 57 pastures that are situated along an elevational gradient of 975–2,134 m crossing three vegetative zones: high-desert chaparral, pinyon-juniper (*Pinus edulis-Juniperus*) woodland, and ponderosa pine (*Pinus ponderosa*) forest (S. McGinley, in litt.). Our study was conducted during a 5-year drought in 2001–2003; 2002 was one of the driest years on record. Long-term (1938–2011) annual precipitation averaged 66.4 cm at the Happy Jack Ranger Station (ca. 45 km NE Camp Verde, Coconino County; Western Regional Climate Data Center, www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?az3828). Rainfall was 9, 35, and 8% below the long-term average during 2001, 2002, and 2003, respectively.

Low-elevation (1,220–1,524 m) sites were in pinyon-juniper woodlands with 0–15% slope. Common grasses were western wheatgrass (*Pascopyron smithii*) and blue grama (*Bouteloua gracilis*) with scattered patches of shrub live oak (*Quercus turbinella*), Utah juniper (*Juniperus osteosperma*), and pinyon pine. Temperatures peaked at 35°C in June and dropped to just below freezing in January. Precipitation averaged 48–56 cm/year and occurred bimodally in summer as rain and during winter as snow.

Middle-elevation (1,525–1,892 m) sites were in the transition zone with slopes of 15–40%. Dominant grasses included blue grama and sideoats grama (*Bouteloua curtipendula*) with large patches of shrub live oak, pinyon pine, and Utah and alligator juniper (*Juniperus deppeana*). However, there was a recent invasion of annual Japanese brome (*Bromus japonicas*) that predominated in early spring and died before most other grasses began growth. Temperatures were similar to low-elevation sites, but slightly cooler year-round, and precipitation averaged 52–60 cm with the same bimodal trend as low-elevation sites.

High-elevation (1,893–2,287 m) sites were in forests of ponderosa pine with slopes of 0–15%. Common grasses included blue grama, western wheatgrass, tall fescue (*Festuca arundinacea*), crested wheatgrass (*Agropyron cristatum*), mountain muhly (*Muhlenbergia montana*), Kentucky bluegrass (*Poa pratensis*), dropseed (*Sporobolus*), and squirrel tail (*Sitanion hystrix*). Forests of ponderosa pine provided the predominant cover with some thickets of shrub live oak and Gambel oak (*Quercus gambelii*), and occasionally, Rocky Mountain juniper (*Juniperus scopulorum*). Temperatures peaked in July at 27°C and dropped to −9°C in early January. Average precipitation was 50–60 cm/year with bimodal peaks in spring and summer.

The grazing plan of the Walker Basin allotment generally scheduled grazing by cattle in low-elevation pinyon-juniper woodlands during spring, middle-elevation transitional zones in early summer, and high-elevation forests of ponderosa pine in late summer and early autumn. The grazing-management plan combined elements of rest-rotation and deferment where livestock were moved in response to growth and phenology of plants, while considering forage needed by elk and other wild herbivores (Halstead et al., 2002). Patterns of movement of cattle among pastures was controlled so that longer grazing periods (≤30 days) occurred when perennial grasses were dormant and shorter grazing periods (≤15 days) occurred when perennial grasses were growing rapidly. Thus, most of the allotment was free from grazing by cattle at any point in time. One of the primary purposes of adaptive grazing management on the allotment was to attract elk to pastures recently grazed by cattle at a particular elevation, while resting adjacent pastures to increase growth of forage and to sustain adequate forage for cattle, elk, and other wild ungulates (Halstead et al., 2002). Since 1999, managers have used adaptive grazing management rather than rigid dates to determine when and where to move livestock on the allotment. Managers periodically evaluated data on current growth of plants, phenology, and long-term monitoring to adjust duration and timing of grazing by livestock.

A severe drought occurred throughout Arizona during our study (J. A. McPhee et al., in litt.). The driest year and lowest production of forage on the Walker Basin allotment occurred in 2002. Consequently, rates of stocking and movements of cattle in each pasture were adjusted throughout the study depending on how precipitation affected available forage as determined by sampling and observation of forage. Due to monitoring of drought and height of stubble, high-elevation pastures (summer range of elk) were grazed by cattle only when key species of forage (e.g., Arizona fescue and mountain muhly) were dormant during all 3 years of our study. In 2002, there was little or no production of forage in low-elevation and middle-elevation pastures, and elk had removed ca. 50% of available forage before cattle entered a pasture. Consequently, grazing by cattle was reduced to ≤8 days in these pastures in 2002.

We collected and measured use of key species of perennial grasses selected from two pastures at each elevation. Important considerations for selection of key species included palatability and availability for elk and cattle. Key species selected included western wheatgrass in low-elevation, blue grama and side-oats grama in middle-elevation, and Arizona fescue, blue grama, dropseed, Junegrass, Kentucky bluegrass, and mountain muhly in high-elevation sites. These species were identified by the United States Forest Service as key species for elk and cattle on the allotment (United States Forest Service, in litt.).

We estimated use of forage by cattle and elk in 2001, 2002, and 2003 at each of the three elevations during 3 sampling periods: immediately before cattle entered a pasture, immediately after cattle left a pasture, and at the end of the growing season. Relative use of forage by elk was measured immediately before cattle entered each pasture. We measured relative use of forage by elk and cattle immediately after cattle left each pasture and total use of forage by elk and cattle at the end of the growing season (Halstead et al., 2002). We measured relative use of forage during the growing season (i.e., immediately before cattle entered a pasture and immediately after cattle left a pasture) and estimated percentage of forage that had been consumed relative to what had grown at the time sampling occurred. We measured total use of forage at the end of the season and estimated percentage of forage consumed during the entire growing season. Growing seasons generally began in March (low elevation), May (middle elevation), and June (high elevation).

We collected data on production of forage, use of forage, and height of residual stubble as described in the Interagency Technical Reference (1996). We randomly located paired-plots in each of six pastures (2 pastures/elevation). Each pasture contained 18 paired plots (one 1.7-m^2 caged plot compared with two uncaged 1.7-m^2 plots) that were divided into three key areas to include variability across each pasture (6 paired plots/key area) for a total of 108 paired plots for all six pastures. Rather than the usual one uncaged plot, two uncaged plots were matched with each caged plot to account for local variability in grazing (Klingman et al., 1943; Grelen, 1967; Bork and Werner, 1999; Halstead et al., 2000). Frames of cages were constructed of rebar and were square at the base and pyramidal in shape. A welded wire mesh (ca. 5 by 7.6 cm) was then attached to the frame. The wire mesh was small enough to exclude lagomorphs. Uncaged plots were delineated by a square base constructed from rebar.

We visually paired each caged macroplot with two uncaged macroplots that were estimated to contain equal biomass and number of species. Prior to selecting paired-plot units, we tested ability of an observer to visually estimate plots that contained similar biomass and detected no difference ($P = 0.690$) in biomass clipped from 10 paired-plot units. The same observer selected all paired plots throughout the study. We located key areas ≥100 m from each other, caged macroplots ≥50 m from their respective uncaged pairs, and uncaged plots within each paired-plot unit ≥10 m apart. We recorded uncaged plots with a GPS unit and marked their location with a wooden stake and two metal rods. Markers were situated inconspicuously to avoid attracting animals to plots. We relocated all plots at the beginning of each growing season ≥10 m from the placement during the previous year to account for grazing of boundaries and possible stagnation of vegetation (Tueller and Tower, 1979).

We used a 0.25-m^2 circular frame to clip three subplots within each 1.7-m^2 macroplot as described by Halstead et al. (2000, 2002). All key species of forage that were rooted within the subplot were clipped to the ground. We dried samples in a forced-air oven at 55–60°C for 48 h and weighed them to the nearest 0.1 g. We averaged the three dry weights of subplots for each caged macroplot. For the two corresponding uncaged macroplots, we averaged dry weights of the six subplots (three subplots times two macroplots). Percentage use for a paired-plot unit was the ratio of averages for uncaged and caged weights. We calculated average use for a key area from two randomly selected paired-plot units that were clipped during a sampling period following Halstead et al. (2000, 2002).

We used caged plots clipped immediately before cattle entered a pasture, during the time they were there, and immediately after cattle left a pasture to measure relative production (kg ha^{-1}) while caged plots clipped during the end of growing season measured total production of forage (Table 1). Likewise, relative residual biomass (kg ha^{-1}) on uncaged plots was measured immediately before cattle entered and immediately after cattle left a pasture and total residual biomass (kg ha^{-1}) of uncaged end-of-season plots was measured. Elk and cattle were assumed to be the primary consumers of graminae on the allotment because deer (*Odocoileus*), jackrabbits (*Lepus*), and pronghorns (*Antilocapra americana*) were uncommon (Halstead et al., 2002). After cattle left a pasture, elk were the most common mammalian herbivores on the allotment.

Typically, rains in the beginning of the growing season (February–June) provided precipitation for cool-season perennial grasses. However, in 2002, there was <3 cm of rain during this period, which resulted in no new growth in low-elevation and middle-elevation pastures. Available forage in low-elevation and middle-elevation pastures primarily consisted of residual grasses produced late in 2001. Hence, in 2002, we separated biomass of growth from the previous year (gold color) from growth older than the previous year (gray color), and then clipped and weighed only gold-colored biomass to estimate use and biomass of forage from samples collected before July 2002. To keep the sampling procedure consistent throughout 2002, we included gold-colored vegetation in all collections of biomass throughout the growing season, along with any new growth that occurred after June (green). We included occasional negative estimates of use of forage from paired plots based on Bork and Werner (1999). Holechek et al. (2004) suggested that 35–45% use of forage would maintain production of forage in semi-arid rangelands; consequently, we classified use of forage <35% as light, 35–50% as moderate, and >50% as heavy.

We sampled height of stubble concurrently with use of forage following the Interagency Technical Reference (1996). We measured heights of 60 key species along a 400-m transect placed between caged and uncaged plots within each study area. We measured height of grazed or ungrazed key species nearest a dot placed on the boot of an observer at 3-m intervals. Key species selected for sampling height of stubble included western wheatgrass in low-elevation, blue grama in middle-elevation, and dropseed in high-elevation sites.

We used a completely randomized design to analyze use of forage and height of stubble with a three-by-three factorial arrangement of treatments. We used a standard least-squares ANOVA to test the effect of year (2001, 2002, 2003), elevation (low, middle, high), sampling period (immediately before cattle entered a pasture, immediately after cattle left a pasture, and at the end of the growing season), and interactions. We applied arc-sine transformation to data for use of forage prior to calculation of percentage (Steel and Torrie, 1980). ANOVA was conducted on arc-sine transformation data for use of forage, but actual averages (%) are reported.

RESULTS—Overall production of forage across the Walker Basin allotment was lower in 2002 (average. 331 ± 25 kg ha^{-1}) than in 2001 (average, 712 ± 75 kg ha^{-1}) or 2003 (average, 479 ± 50 kg ha^{-1}; Table 1). Production of forage across years closely paralleled precipitation. Low-elevation pastures were most productive (average, 637 ± 102 kg ha^{-1}), followed by high-elevation (average, 518 ± 42 kg ha^{-1}) and middle-elevation pastures (average, 368 ± 36 kg ha^{-1}; Table 1). Low-elevation pastures consisted mostly of a monoculture of western wheatgrass that was seeded in 1966–1968 and contributed to higher production of forage compared to middle-elevation and high-elevation pastures where naturally growing native grasses were dominant herbaceous vegetation.

Use of forage was influenced by the year-by-elevation interaction ($F_{4, 301} = 12.71$; $P < 0.001$) and the elevation-by-sampling-period interaction ($F_{4, 301} = 5.39$; $P < 0.001$). In years of higher precipitation (2001 and 2003), use of forage by elk and cattle was less in middle elevations (19.7 ± 3.2 and 24.1 ± 7.3%) compared to low (40.6 ± 4.6 and 33.2 ± 4.9%) and high (38.5 ± 4.5 and 34.5 ± 6.0%) elevations (Fig. 1a). In the worst year of drought (2002), use of forage by elk and cattle increased with elevation (Fig. 1a).

Average relative use of forage by elk immediately

Table 1—Average production of forage (kg ha^{-1}) across sampling periods and elevations on the Walker Basin allotment, Coconino and Yavapai counties, Arizona, 2001–2003.

Elevation	Sampling period	Year 2001	Year 2002	Year 2003	Overall average
Low (1,220–1,524 m)	Immediately before cattle entered a pasture	985	305	434	575
	Immediately after cattle entered a pasture	933	379	829	714
	Total use of forage at end of growing season	1,040	299	525	621
Middle (1,525–1,892 m)	Immediately before cattle entered a pasture	470	252	459	394
	Immediately after cattle entered a pasture	457	287	316	353
	Total use of forage at end of growing season	512	224	334	357
High (1,893–2,287 m)	Immediately before cattle entered a pasture	605	440	542	529
	Immediately after cattle entered a pasture	711	373	456	513
	Total use of forage at end of growing season	698	422	415	512
Overall average		712	331	479	508

before cattle entered a pasture was light to moderate in all years (i.e., 17.3 ± 3.8, 38.7 ± 4.7, and 9.5 ± 5.9% for 2001, 2002, 2003, respectively), whereas relative use of forage by elk and cattle was moderate in all years immediately after cattle left a pasture (i.e., 38.9 ± 4.1, 47.8 ± 5.2, and 42.9 ± 5.4% for 2001, 2002, 2003, respectively; Fig. 2). Average use of forage at the end of season by elk and cattle was higher in 2002 (58.1 ± 3.3%) than in 2001 (40.7 ± 4.6%) or 2003 (39.4 ± 4.4%). Overall, use of forage was higher in 2002 (48.6 ± 2.7%) than in 2001 and 2003 (33.7 ± 2.6 and 30.6 ± 3.4%, respectively; Fig. 2).

Height of residual stubble, like use of forage, was influenced by the year-by-elevation ($F_{4,\ 135} = 36.76$; $P < 0.001$) and elevation-by-sampling-period ($F_{4,\ 135} = 5.8$; $P < 0.001$) interactions. There also was evidence of a year-by-sampling-period interaction ($F_{4,\ 135} = 2.24$; $P = 0.068$). Height of stubble averaged 14.6 ± 1.4, 9.4 ± 1.7, and 28.2 ± 4.1 cm for the low, middle, and high elevations, respectively, in pastures that were grazed only by elk (i.e., immediately before cattle entered a pasture). Due to different species of graminae being sampled at each elevation, data on height of stubble immediately before cattle entered a pasture confirmed that blue grama was inherently the shortest (middle elevation), western wheatgrass was intermediate (low elevation), and species of dropseeds were the tallest (high elevation) grasses.

Data for height of stubble also confirmed that severe drought greatly impacted height of plants. Average height of stubble was shortest in 2002 (9.6 ± 0.4 cm), followed by 2001 (14.6 ± 1.1 cm), and 2003 (26.2 ± 2.2 cm; Fig 1b). Average height of stubble across elevations at the end of the growing season was taller than immediately before cattle entered a pasture during 2001 (17.1 ± 1.6 versus 14.4 ± 2.1 cm) and 2003 (29.6 ± 2.7 versus 26.7 ± 4.4 cm), but was similar during 2002 (8.6 ± 0.79 versus 11.1 ± 0.7 cm; Fig. 3). Thus, some regrowth occurred in 2001 and 2003 as opposed to little or no regrowth in 2002 due to severe drought. Shorter stubble generally corresponded to lower production and higher use of forage, and vice versa.

Discussion—There was light use of forage by elk at low elevations immediately before cattle entered a pasture in 2002 compared to higher use of forage by elk in middle-elevation and high-elevation pastures. Elk likely migrated

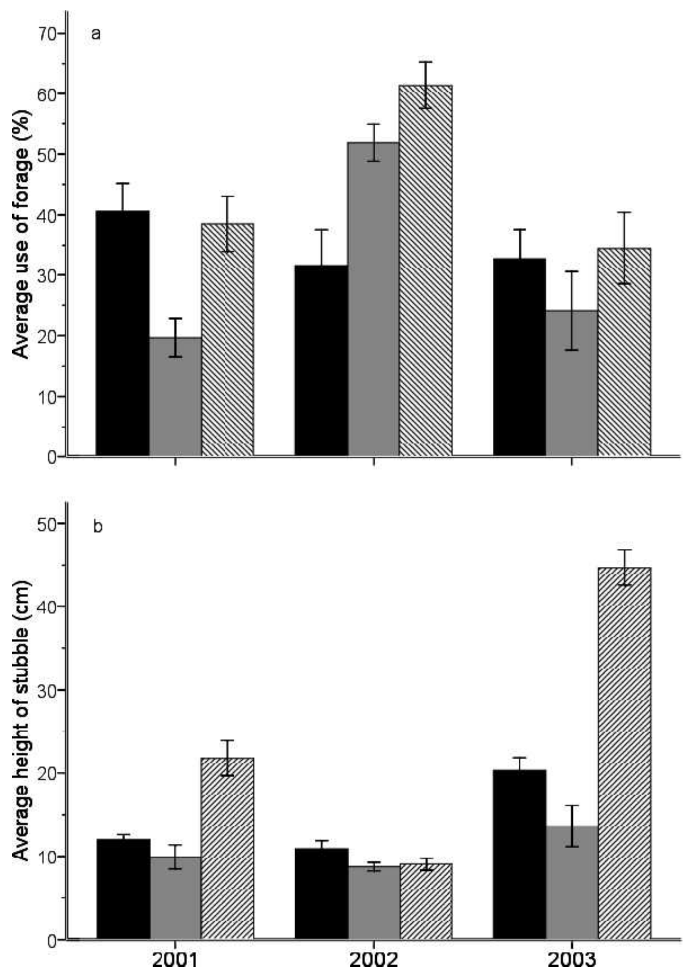

Fig. 1—Average a) use of forage and b) height of stubble during 2001–2003 on the Walker Basin allotment, Coconino and Yavapai counties, Arizona, in low-elevation (black bars), middle-elevation (gray bars), and high-elevation pastures; error bars denote *SE*.

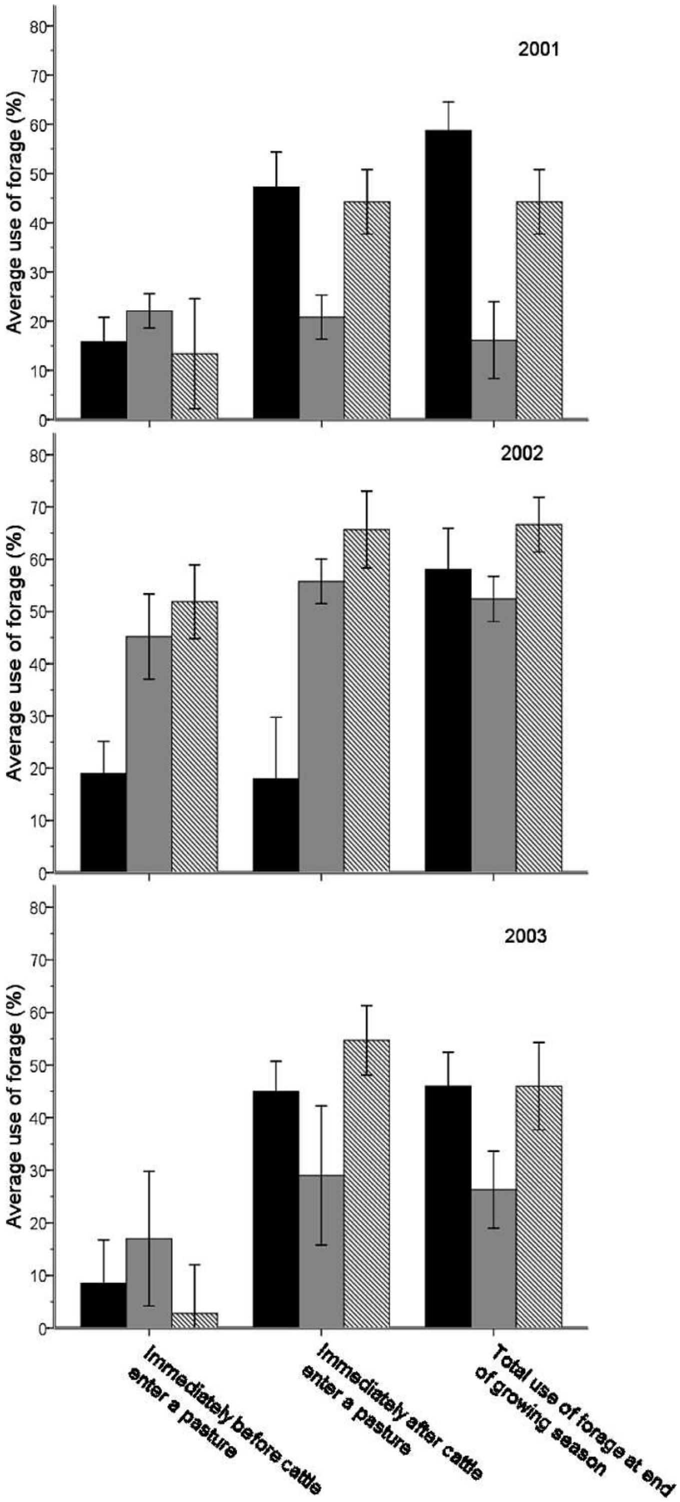

FIG. 2—Average relative use of forage by elk (*Cervus elaphus*) immediately before cattle (*Bos taurus*) entered a pasture, elk and cattle immediately after cattle entered a pasture, and total use of forage by elk and cattle during the growing seasons of 2001–2003 on the Walker Basin allotment, Coconino and Yavapai counties, Arizona, in low-elevation (black bars), middle-elevation (gray bars), and high-elevation pastures; error bars denote *SE*.

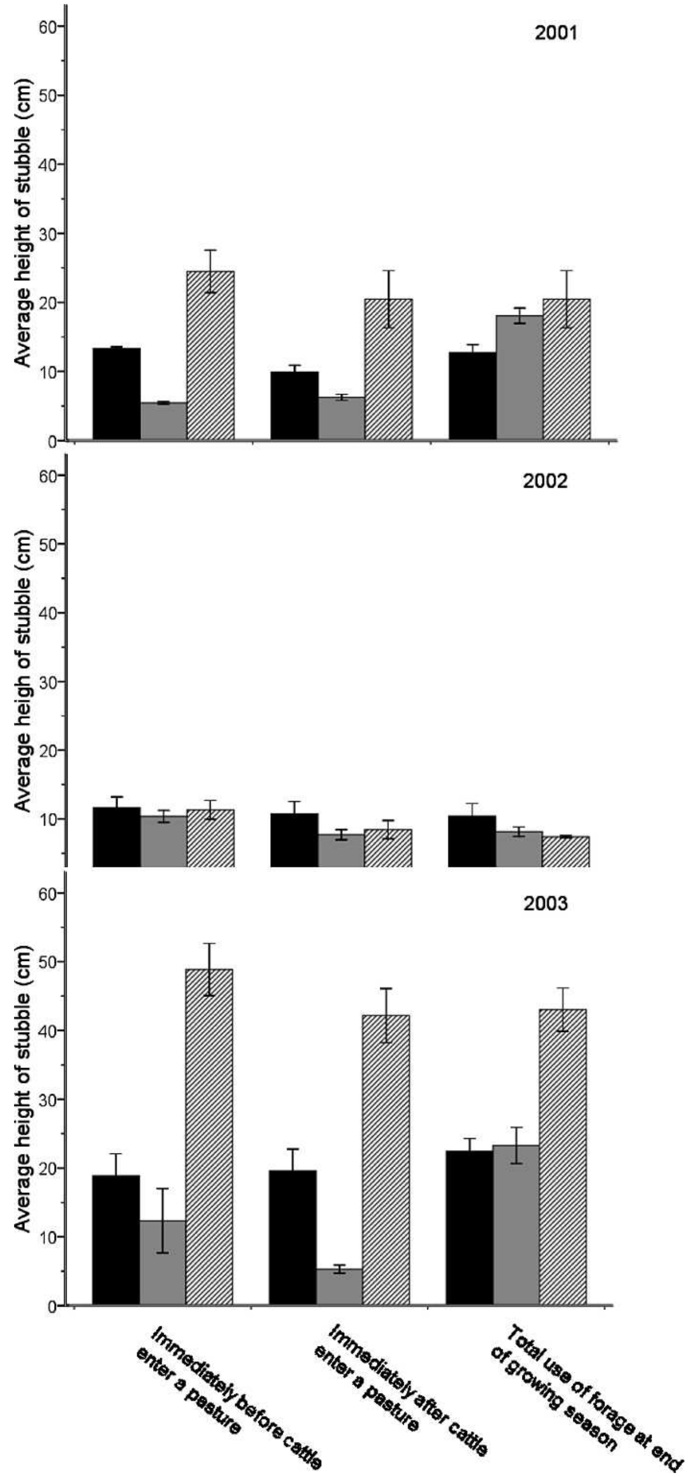

FIG. 3—Average relative height of stubble following use of pastures by elk (*Cervus elaphus*) immediately before cattle (*Bos taurus*) entered a pasture, elk and cattle immediately after cattle entered a pasture, and total use of forage by elk and cattle during the growing seasons of 2001–2003 on the Walker Basin allotment, Coconino and Yavapai counties, Arizona, in low-elevation (black bars), middle-elevation (gray bars), and high-elevation pastures; error bars denote *SE*.

from lower to higher elevations in response to a lack of forage in low-elevation pastures in 2002 as observed by Marcum and Scott (1985). We observed more fecal pellets of elk and we saw more elk in 2002 while we were sampling vegetation in middle-elevation and high-elevation pastures compared to low-elevation pastures. Conversely, in 2001 and 2003, immediately before cattle entered a pasture, use of forage by elk was ≤22% at all elevations.

Middle-elevation pastures were considered by Halstead et al. (2002) to be transition zones for elk between low (winter) and high (summer) ranges. Middle-elevation pastures received light grazing pressure from elk (i.e., ≤22%) during 2001 and 2003, when production of forage was higher; conversely, immediately before cattle entered a pasture, use of forage by elk increased at middle elevations during 2002 when production of forage was at its lowest point during our study.

Use of forage at the end of the growing season by elk and cattle was >50% once in 2001 (i.e., 59% at low elevation) and once in 2002 (i.e., 67% at high elevation). However, combined use of forage at the end of the growing season by elk and cattle was <50% at any of the three elevations for 2 consecutive years during our 3-year study. Overall, average use of forage across the three elevations was 37%.

Height of stubble, while related to use of forage, typically is measured as an indicator of protection of soil from erosion by wind and water (Halstead et al., 2002). Higher use of forage by elk occurred after cattle left a pasture, which typically corresponded to shorter stubble and greater use of forage. Guidelines recommended by Holechek et al. (2004) for height of stubble on rangelands were: low elevation, 8 cm; middle elevation, 4 cm; and high elevation, 15 cm. Height of stubble at the end of the growing season was below these guidelines once during 2002 at high elevation (i.e., 7 cm). During less-severe years of drought (2001 and 2003), height of stubble at the end of the growing season was taller (i.e., 17 and 30 cm during 2001 and 2003, respectively) than immediately before cattle entered a pasture (i.e., 14 and 27 cm during 2001 and 2003, respectively). This illustrates that regrowth in autumn can confound interpretation of estimates of relative use of forage and height of stubble before growth is complete at the end of the growing season.

When rates of stocking are held constant, drier years typically were correlated with less production of forage, greater use of forage, and shorter stubble compared to wetter years (Pepper, 2004). In a review of studies of stocking rates conducted in the Southwest, Holechek et al. (2004) observed that use of forage averaged 55–60% during drought years and ca. 20–25% in wet years. In our study, ongoing drought likely depressed production of forage during every year. Drought, while prevalent throughout our study, was most severe during 2002 as indicated by production and use of forage, and by height of stubble. Moreover, production of forage measured at low and middle elevations in 2002 actually was produced in 2001. Managers of rangelands on the Walker Basin allotment responded to drought by shortening the time of grazing by cattle in low-elevation and middle-elevation pastures during 2002 (Pepper, 2004). Moreover, managers also did not permit grazing in high-elevation pastures when key species of forage were growing during all 3 years of our study.

Although guidelines for proper use of forage derived from studies of grazing in the Southwest are averages that contain considerable variability, maintaining average use of forage at 30–50% over a 5–10-year period will provide continued productivity (Holechek et al., 1999; Smith et al., 2005). Estimates of relative use of forage (i.e., immediately before cattle entered a pasture and immediately after cattle left a pasture) made during our study reflected measurements of use and production of forage up to a point in the growing season. While estimates of relative use or forage can help identify current patterns of distribution of large herbivores, guidelines for use of forage cannot be developed for estimates of relative use of forage because there is no consistent relationship between estimates of relative (seasonal) use of forage and use of forage at the end of the growing season (Smith et al., 2005). Estimates of use of forage require an estimate of current production of annual forage that can be obtained only at the end of the growing season. Therefore, it is important to make the distinction between relative use of forage (i.e., immediately before cattle entered a pasture and immediately after cattle left a pasture in our study) versus use of forage (i.e., end of the growing season in our study) when making decisions about adaptive grazing management.

Previous research reported discrepancies in accuracy of caged plots to estimate growth of vegetation with the paired-plot method (Grelen, 1967; Sharrow and Motazedian, 1983; Bonham, 1989; Biondini et al., 1991; Halstead et al., 2000). Effects of cages on insolation, humidity, temperature, intensity of precipitation, support, and movement of wind may influence growth inside cages (Owensby, 1969). Some other factors that can cause discrepancies are: protected plots do not take compensatory growth into account; loss of vegetation due to trampling in uncaged plots; clipping plants does not replicate the grazing process exactly; not all vegetation measured is at peak standing crop; birds and small mammals fertilize and re-seed caged plots; and it is difficult to measure only 1 year of perennial growth (Klingman et al., 1943; Frost et al., 1994). The paired-plot technique is imprecise unless the sample is large (Klingman et al., 1943). The advantage of caged plots is that they provide a baseline of plants not subjected to grazing while most other methods only estimate what is absent. Estimates made with the paired-plot technique that are supplemented with another metric (e.g., height of stubble) can provide a more complete assessment of the effects of use of forage by wild and domesticated herbivores (Halstead et al., 2002).

Our study illustrates the importance of evaluating dynamics of use of forage by elk and cattle locally on a case-by-case basis. Although combined use of forage at the end of the growing season by elk and cattle was >50% in low-elevation and middle-elevation pastures on one occasion during our 3-year study, overall use of forage across elevations on the allotment averaged 37%. Use of forage did not exceed 50% at any of the three elevations for 2 consecutive years, although our study was conducted during one of the worst droughts in the history of Arizona (Western Regional Climate Data Center, www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?az3828). Likewise, height of stubble at the end of the growing season was below recommended guidelines only once at high elevation during 2002 when drought was most intense. The Walker Basin allotment was the only ranch in the area that was granted permission by the United States Forest Service to graze upper-elevation pastures in 2002. All other allotments in the area had heights of stubble that were unacceptable in high-elevation pastures.

In a recent review, Smith et al. (2005) described fundamental principles of collecting and interpreting data on use of forage for making management decisions. Managers should evaluate use of forage on a case-by-case basis over a 5–10-year period and carefully consider factors that can influence autecology and synecology of plants (e.g., timing, intensity, frequency of grazing, historical use, kind of animals, current and historical precipitation, trends in vegetation; Holechek et al., 2004). Adaptive management as used on the Walker Basin allotment considers many of these factors. For example, each pasture typically is grazed ≤20 days/year after set of seeds or dormancy of plants, but in years of severe drought, as in 2002, grazing in each pasture was reduced to ≤5 days.

Multiple-species grazing systems need to consider how livestock influence spatial and temporal movements of wild ungulates through seasons and elevations. Management plans should accommodate all animals involved in the rangeland ecosystem (Cook, 1962). In situations like 2002, where upper elevations received greatest use of forage, new management techniques should be developed to quickly alleviate possible problems. For example, culling of elk through hunting (Wisdom and Thomas, 1996; Lyon and Christensen, 2002) or limiting use by cattle in problem areas could be implemented to avoid deterioration of the rangeland.

On arid rangelands where climate is variable across space and time, long-term averages for use of forage and height of stubble are helpful in evaluating cumulative effects of the response of plants to herbivory. This evaluation should include long-term data on use of forage, precipitation, and trends in vegetation (Smith et al., 2005). Adaptive grazing management on the Walker Basin allotment was a key component in addressing use and production of forage for cattle and elk during drought in the short-term and health of rangeland in the long-term (Moir and Block, 2001).

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