The Effects of a Rotational Cattle Grazing System on Elk Diets in Arizona Piñon–Juniper Rangeland

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If it weren't for all the cattle out here we would have enough forage for our elk …

We had planned for 3 weeks of grazing in this pasture but the elk beat us to it …

It is not uncommon to hear statements such as these in the western United States. Dietary overlap between cattle and wild herbivores such as elk or deer has been reported in various regions, seasons, and ecosystems.[1] Competition between two species occurs when a shared resource is in limited supply or when the presence of one species disturbs the other. The simple fact that space and forage resources are shared might or might not, however, constitute a negative interaction between cattle and elk.[1] Studies in central Arizona[2] found that although diet similarity was high in certain years and seasons, there was actually little inter-specific competition between cattle and elk overall. Factors such as scale, season, and forage availability influence the likelihood and degree of competition. Overgrazing is detrimental to sustained livestock and wildlife productivity. Livestock grazing can, however, be applied to positively manipulate habitat for wildlife. A review by Krausman et al.[3] cites a Montana case study in which a rotational cattle grazing system "maintained productive cover and forage for elk while enhancing native vegetation condition on all of the managed areas."

Previous studies on the subject of diet composition and overlap have employed a variety of methods, such as microhistological analysis of feces or observation of grazing animals to obtain dietary information.[4] New technology is available to facilitate research and management of grazingland animals. Near infrared spectroscopy (NIRS) is a rapid, noninvasive analytical technique that has been broadly applied in agriculture. Australian wildlife ecologist William Foley and his colleagues[5] outlined the advantages and disadvantages of NIRS and argued for increased application of the technique in ecological and natural resource disciplines. Near-infrared spectroscopy of feces has been applied to the study and management of grazing animal nutrition.[6] Specifically, diet quality has been predicted using this technique in livestock and wildlife species. Similarly, fecal NIRS has been used to determine diet composition of small and large ruminant livestock. Fecal NIRS also has been used to discriminate among various species of sympatric herbivores, but the technique has not been as widely applied to compare dietary attributes such as similarity in quality or composition. More research is needed to determine the practical usefulness of these techniques in managing the nutritional environment for potentially competing species such as cattle and elk on western rangelands.

We conducted research on a public land ranch in Arizona to test the hypothesis that a rotational cattle grazing system could increase palatable re-growth and attract elk to piñon–juniper rangeland recently grazed by cattle. If true this ractice would provide substantial rest to one half of the allotment in this area each year. According to the Arizona Game and Fish Department, elk was the primary wild herbivore that significantly used western wheatgrass (*Pascopyrum smithii* [Rydb.] A. Löve), the key forage species used in previous cattle and elk grazing research by our group.[7] In the current study, we examined diet quality and composition by performing two different fecal analyses on samples collected in: 1) 1997 and 1998, 2) summer and fall, and 3) pastures grazed versus not grazed by cattle. Our overall objectives were to: 1) use established fecal indices (NIRS and microhistological analyses) to examine the effects of a rotational cattle grazing system on dietary attributes for elk and cattle, and, 2) evaluate the effectiveness of a composite diet technique to develop fecal NIRS diet composition calibrations for elk.

The V Bar V Ranch

The University of Arizona's V Bar V Ranch (Fig. 1) operates on the Walker Basin allotment (lat 34°38′30″N, long 111°40′40″W), which consists of approximately 31,000 ha of rangeland on the Coconino National Forest in central Arizona. Winters in this area are mild (average 8°C/46°F);

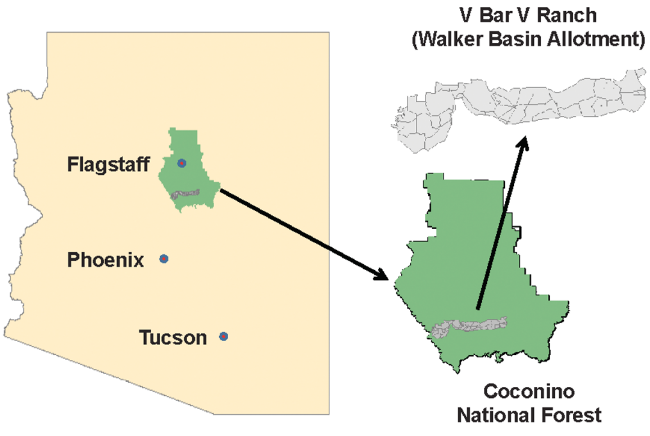

Figure 1. Location of V Bar V ranch.

summers are hot (average 27°C/80°F). May and June are historically dry, with a convectional thunderstorm "monsoon" precipitation pattern occurring in July through September. The ranch has three distinct climate and vegetation communities: desert–shrub, piñon–juniper, and ponderosa pine (Fig. 2). Our study area (about 6,750 ha) consisted of four pastures (850 to 2,100 ha in size) on the piñon–juniper range (Fig. 3). This area was chosen because local resource managers indicated a high potential for elk and cattle competition in this transitional zone between winter and summer range. The growing season at this elevation is generally from March to October.

Western wheatgrass was the key herbaceous forage species in the study pastures. Other plant species included blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths), sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.), downy brome (*Bromus tectorum* L.), buckwheat (*Eriogonum* spp.), snakeweed (*Gutierrezia sarothrae* [Pursh.] Britton & Rusby), skunkbush sumac (*Rhus trilobata* Nutt.), turbinella oak (*Quercus turbinella* Greene), piñon pine (*Pinus edulis* Engelm.) and Utah juniper (*Juniperus osteosperma* [Torr.] Little). Soils are primarily described as moderately deep, cobbly clay loams.

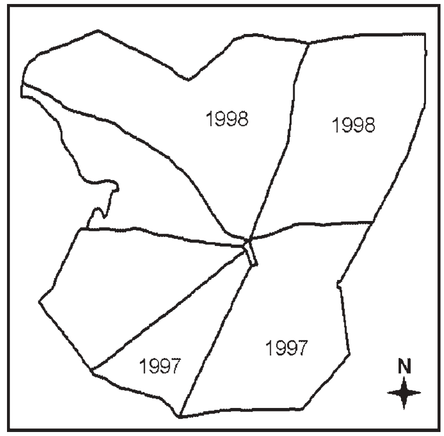

Figure 3. Pastures grazed by cattle within Cedar Flats grazing unit, Walker Basin allotment in 1997 and 1998.

The Grazing System

Cattle used in this study were predominantly moderate-framed *Bos taurus* cross commercial beef cows (450 ± 5 kg). During 1997, 413 cow–calf pairs grazed the experimental pastures, and 450 cow–calf pairs grazed in 1998. Breeding roughly coincided with the growing season in this study; the bull to cow ratio was 1 to 15. As specified in the allotment management plan, each year during the growing season lactating cattle were moved up the elevational gradient through two of the four study pastures (about 14 days per pasture) on one half of the allotment and then after weaning during the dormant season, moved down the elevational gradient through the same pastures (about 5 days per pasture). The two southern pastures were grazed by cattle in 1997 and the two northern pastures were grazed by cattle in 1998 (Fig. 3). To illustrate the relative amount of rest received by each of the pastures as they were used in this study, when cattle entered the southern pastures in summer of 1997, these pastures had not been grazed since fall of 1995. And when cattle entered the northern pastures in 1998, the pastures had not been grazed since fall of 1996. Average

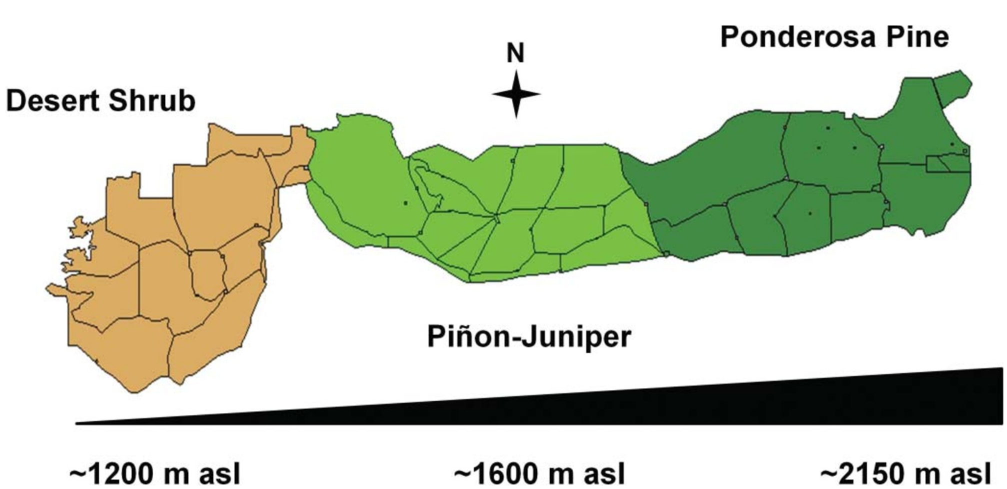

Figure 2. Vegetation types and elevation: V Bar V ranch.

Table 1. Effect of year, season, and cattle grazing on elk diet composition from piñon–juniper rangeland as determined by microhistological analysis of feces												
	Summer						Fall					
	Grazed			Rested			Grazed			Rested		
Plant category	No.*	Mean	SE†	No.	Mean	SE	No.	Mean	SE	No.	Mean	SE
1997												
Grass	4	65.3	4.0	4	63.2	5.4	4	48.6	1.2	4	51.1	3.2
Sedge	1	1.4	NA	1	1.1	NA	0	NA	NA	0	NA	NA
Forb	4	28.2	4.8	4	26.5	1.6	4	28.0	5.0	4	27.9	1.4
Shrub	4	5.0	1.3	4	7.0	4.5	4	15.6	4.2	4	13.3	2.7
Conifer	2	2.1	1.1	2	3.0	0.2	4	7.3	1.6	4	7.7	2.3
1998												
Grass	4	58.03	2.82	4	64.3	5.1	4	56.5	7.8	4	60.1	6.8
Sedge	0	NA	NA	0	NA	NA	2	0.9	0.4	0	NA	NA
Forb	4	20.03	5.24	4	21.3	3.6	4	26.8	6.0	4	21.5	7.9
Shrub	4	13.35	1.98	4	6.2	2.3	4	8.0	1.6	4	8.6	3.0
Conifer	4	8.23	2.69	4	8.3	3.5	4	8.2	3.8	3	12.3	4.2

*Number of fecal samples in which each plant category was present and could be measured.
†Standard error of the mean.
NA indicates not applicable.

stocking rates for cattle, calculated using definition "a" of the Glossary Revision Special Committee report[8] were 5.1 and 6.9 ha per AUM during 1997 and 1998, respectively. All pastures were accessible to elk during the entire study.

Fecal Collection and Analyses

Cattle and elk feces were collected in 12, randomly established, 3-ha sampling areas (three sampling areas per pasture) which corresponded to forage utilization and stubble height data collected in our previous research.[7] Each year during these vegetation measurements, we gathered a composite sample (~100 g field weight) from 10 to 20 fecal pats or pellet groups within each sampling area. Cattle feces were collected within 24 hours of deposit, whereas elk feces were estimated by appearance to have been collected within 1 week of deposit. Our fecal sampling schedule differed somewhat between cattle and elk. Cattle samples were gathered in mid-June to early July, at the end of their grazing period in these pastures. Elk fecal material was gathered in the two pastures that were grazed by cattle and in the two pastures that were not grazed by cattle in early to mid-June (i.e., immediately before cattle entered the grazed pastures), and in mid-October just before cattle grazed a given pasture during the dormant season.

After we collected the fecal samples, they were frozen (−20°C) and stored until processed for NIRS. The NIRS scanning procedures have been previously described by Tolleson et al.[9] Diet crude protein (CP) and digestible organic matter (DOM) for both cattle and elk were predicted using the NIRS calibration models of Stuth et al.[10] We determined fecal nitrogen (N) and phosphorus (P) by applying the NIRS calibrations of Tolleson et al.[11] Diet composition for cattle and elk was estimated via microhistological analyses of feces.[12] Plant fragments within feces were identified to species but we subsequently grouped these data into the following categories: 1) grass, 2) sedge, 3) forb, 4) shrub, and 5) conifer.

We determined the differences in diet characteristics between years, seasons, and treatments using analysis of variance procedures.[13] We developed fecal NIRS calibration data by pairing diet composition values for an individual sample with the corresponding near-infrared spectrum.[6] Discrimination of fecal spectra between treatment groups was accomplished as described by Tolleson et al.[9] Differences in proportion of correct identifications between groups were identified by χ^2 procedures.[13] We established the degree of relationship between specific diet quality and composition characteristics using simple linear regression.[13]

Diet Composition

Cattle consumed a diet of predominately grass, and to a lesser extent, forbs. Cattle diets contained more grass in 1998 (90.2 ± 2.2%) than 1997 (80.7 ± 2.7%). The opposite was true for forbs; cattle selected more of these plants in

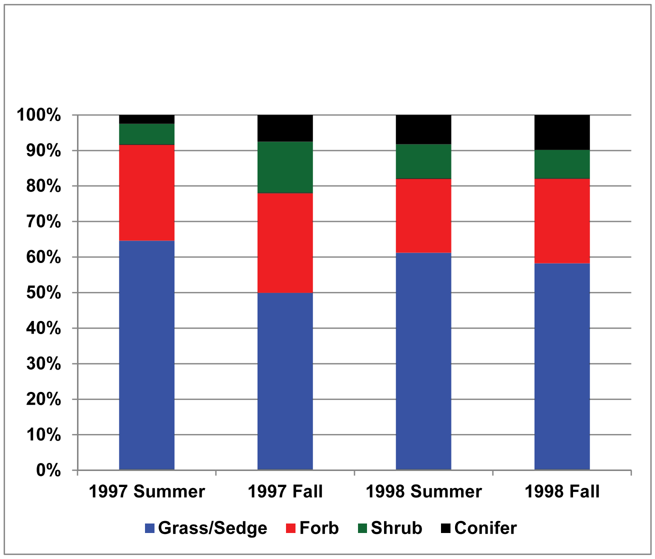

Figure 4. Effect of year and season on elk diet composition from piñon–juniper rangeland as determined by microhistological analysis of feces.

1997 (18.6 ± 2.2%) than in 1998 (8.7 ± 1.7%). Cattle selected approximately 1% sedges in 1997 and approximately 2% shrubs in 1998.

Overall, elk consumed a greater variety of plants than cattle (Table 1), approximately 58% grass, 25% forbs, 9% shrubs, 7% conifers, and 1% sedges. Elk diet composition was not affected by year with the exception that they tended to select more forbs in 1997 than in 1998. Grass consumption by elk was approximately 10% greater in the summer than in the fall. Elk varied their consumption of shrubs across season and year (Fig. 4). In 1997, shrub consumption in the summer was about half that recorded in the fall. In contrast, for 1998 these two seasonal values were similar at approximately 9%. There were no significant differences in elk diet composition due to grazing treatment.

Overall proportions of the various plant species in cattle and elk diets were as expected and agree with the general classification of cattle and elk as grazers and intermediate feeders, respectively. Our values are similar to those reported by Brown[14] for piñon–juniper range approximately 50 km east of our study area which was managed as a "Savory Grazing" system in the mid-1980s. Diet similarity between cattle and elk ranged from 60% to 77% in this study. Our findings are different than those of Miller et al.[2], who reported grass consumption by elk at approximately 80% and diet similarity with cattle above 90%. His study was conducted in the early 1990s in ponderosa pine habitats approximately 25 km east of our study location; the grazing system used in this study was described as a deferred rotation.

Growing season precipitation in our study was above average in 1997 (~400 mm) and near average in 1998 (~300 mm). This amount and timing of moisture appeared to cause a slight shift in elk selection to more forbs in the wetter year. Cattle also were apparently influenced by yearly differences in precipitation, consuming more forbs and less grass in 1997 than in 1998. Although there were more cattle in 1998 and time spent in the pastures was similar, stocking rate was lower than the previous year due to larger pastures used in 1998. Perhaps at similar stocking rates, differences in these observed diet proportions would have been more pronounced.

Cattle grazing as applied in this study did not affect the overall proportion of plant species consumed by elk (Table 1). Elk were found in pastures that were grazed by cattle as well as in pastures rested from cattle grazing. Additional observations from previous research[7] in this area found that elk use was higher in pastures with heavier tree cover and steeper terrain (i.e., the two northernmost) in both years, regardless of where cattle grazing occurred. Elk grazing patterns were apparently more dependent on tree cover and topography than any changes in forage caused by the grazing system.

When considering just the pastures grazed by cattle each year there was, however, less grass consumption by elk after cattle grazing than before. This observation could be due to a combination of cattle removing grass material and to the timing during which elk feces were collected. In early June prior to cattle grazing, ungrazed perennial grasses were green and actively growing. In the fall, perennial grasses might have been transitioning into dormancy, which made them less attractive to elk, as confirmed by less grass in the second collection of elk fecal material.

Wisdom and Thomas[1] discussed 12 generalizations about the interactions between elk and cattle; several of these seem to apply to our study. These authors' assert that cohabitation by cattle and elk does not always result in competition. As expected, competition for forage will be greater in less productive years, seasons, or habitats. On more productive ranges, these two species often distribute themselves in time and space, which minimizes competition. Furthermore, both species exhibit diet plasticity, which allows adaptation to changing forage conditions. Simply put, diet plasticity is the willingness and ability of an animal to adapt their diet to the prevailing conditions. In our study, elk exhibited greater plasticity across time and space than did cattle. Miller et al.[2] reached similar conclusions regarding competition between cattle and elk at higher elevations near our study area, namely that evaluation of competition "must include consideration for diet similarity, range overlap, timing of use, and forage available…"

Diet Quality

Cattle selected a lower quality diet than elk (7.88 ± 0.44% CP and 58.36 ± 0.62% DOM versus 11.06 ± 0.54% and 60.53 ± 0.56%, respectively). Cattle consumed a diet higher in DOM in 1997 (59.68 ± 0.90%) than in 1998 (57.05 ± 0.35%). Cattle fecal N (1.49 ± 0.23%) was less than that observed for elk (1.96 ± 0.06%). Fecal P was similar between the two species (approximately 0.3%).

Overall diet quality (CP and DOM) was generally greater for elk in summer than in fall (Table 2). Diet quality was

Table 2. Effect of year, season, and cattle grazing on elk diet quality from piñon–juniper rangeland as determined by near infrared spectroscopy of feces

Diet/Fecal constituent	Summer						Fall					
	Grazed			Rested			Grazed			Rested		
	No.*	Mean	SE†	No.	Mean	SE	No.	Mean	SE	No.	Mean	SE
1997												
Diet CP	4	12.64	0.74	4	12.15	0.31	3	10.03	0.58	4	10.33	0.68
Diet DOM	4	62.46	0.56	4	62.42	0.28	3	58.86	0.78	4	59.68	0.60
Fecal N	4	2.10	0.22	4	2.00	0.04	3	1.88	0.07	4	1.84	0.08
Fecal P	4	0.36	0.04	4	0.32	0.02	3	0.30	0.02	4	0.37	0.04
1998												
Diet CP	4	10.10	1.55	4	13.76	1.00	4	8.73	0.29	3	10.29	0.48
Diet DOM	4	59.94	0.99	4	62.98	0.89	4	58.62	0.63	3	58.32	0.79
Fecal N	4	1.86	0.27	4	2.18	0.17	4	1.96	0.13	3	1.95	0.10
Fecal P	4	0.29	0.05	4	0.27	0.05	4	0.33	0.08	3	0.32	0.04

*Number of fecal samples collected.
†Standard error of the mean.
CD indicates crude protein; DOM, digestible organic matter; N, nitrogen; P, phosphorus.

not the same within grazing treatments each year (Fig. 5). In 1997, diet quality was similar between samples collected from grazed and rested pastures but in 1998, diet quality was lower in the grazed than in the rested treatment. There were no differences detected for fecal N or P in elk due to year, season, or treatment. Cattle and elk diet CP were both positively correlated with fecal N ($r^2 = 0.58$ and 0.61, respectively).

Diet quality generally agreed with the results from diet composition. Again it was not surprising that elk diets containing more forbs and shrubs were higher in protein than cattle diets. One factor that might have exaggerated our observed differences in cattle versus elk diet quality was that we sampled cattle feces once at the end of the grazing period in their respective pastures. As opposed to elk, cattle were restricted to a defined area, and so even at moderate stocking rates, would have had lower quality forage available to harvest, especially after perennial grasses began to go to seed.

Elk fecal samples were collected in both the summer (before cattle grazing) and the fall (after cattle grazing). The effects of cattle grazing on elk diets are somewhat confounded with the effects of changing seasonal forage conditions as suggested earlier. For comparison, in a recent 2-year cattle diet quality study on the V Bar V Ranch,[15] CP and DOM averaged approximately 11% and 60% in June, and 7% and 58% in October, respectively. Elk diet quality in the current study declined similarly from summer to fall. As with diet composition, there were no direct effects on diet quality by cattle grazing, but there was a difference between years. Elk diet quality was similar between treatments in the wetter year and lower in grazed than rested pastures in the drier year (Fig. 5). End-of-season total forage use was higher in 1998.[7] Drought is a way of life on many rangelands shared by livestock and wildlife; rested pastures should facilitate adaptability by wildlife through provision of forage quantity and quality.

Fecal N and diet CP were correlated in both cattle and elk. The relationship within elk samples was not strong enough to statistically detect the same differences in diet

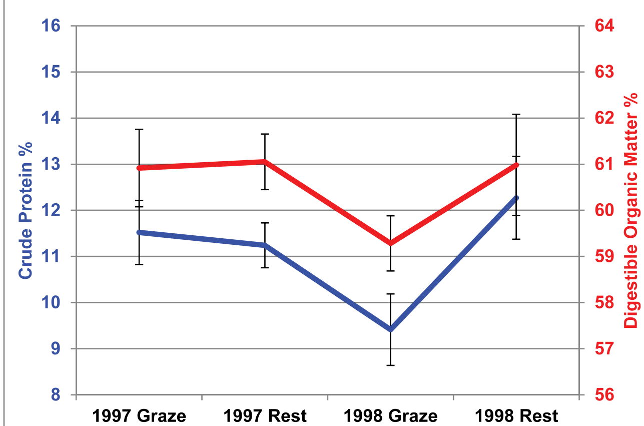

Figure 5. Effect of year and season on elk diet quality from piñon–juniper rangeland as determined by near infrared spectroscopy of feces.

due to season or treatment with both methods. Fecal N has long been applied to infer diet quality in grazing animals. Leslie et al.[16] have reported on the instances in which fecal N is an appropriate measure for diet quality. Our study with elk seems to fit their criteria. Fecal N is most often easier to obtain than dietary N or CP via fecal NIRS, especially if a diet quality calibration does not currently exist for a given species. If a fecal NIRS diet calibration does exist, the determination of diet CP should be more informative with respect to environmental or management influences than fecal N.

NIRS Calibration and Discrimination

Proportion of grass in elk diets was weakly correlated ($r^2 = 0.14$) with fecal NIRS-predicted CP. No other diet constituents were correlated with either fecal NIRS-predicted CP or DOM. The fecal NIRS calibration for proportion of grass in elk diets was not highly predictive ($R^2 = 0.37$, standard error of cross validation = 8.8).

Discrimination between fecal spectra from cattle and elk was 100% correct as was the discrimination between elk samples collected before versus after cattle grazing. Samples from 1997 were correctly identified at a 93% rate versus 87% for 1998. Elk samples collected from grazed versus rested pastures were not highly discriminated (53 and 60%, respectively). Discrimination between elk samples grouped by relative proportions of grass consumption were only moderately successful (approximately 60% correct). Numerical predictions of the proportion of plant categories in cattle and elk diets via fecal NIRS were largely unsuccessful ($r^2 < 60\%$). This was attributed to the amount of sampling error involved in matching composite fecal samples with diet proportion data. Fecal NIRS has been used to predict livestock diet composition of various forage species[6] when either pen-fed or grazing observation data were matched to individual animals. The successful discrimination between fecal samples from cattle and elk is similar to results reported for sympatric domestic and wild herbivores (> 80% correct).[6] Discrimination between elk samples from different years, seasons, or grazing treatments agreed with our diet quality predictions.

Management Implications

The grazing system as applied in this study did not accomplish the management goal to attract elk to pastures recently grazed by cattle and reduce grazing pressure on the rested pastures. Moderate cattle grazing in a rotational system did allow elk to select a diverse and high quality diet in this piñon–juniper habitat. Our results also contributed to a change in grazing management on this allotment. Cattle are currently moved up the elevational gradient on the north pastures in summer and then back down the south side in late fall during even-numbered years. Grazing in the opposite direction (south-summer, north-fall) occurs in odd numbered years. By so doing, no pasture is grazed twice in a given year and the summer-grazed pastures are not grazed again until the next fall/winter. Hence, each pasture is rested during the summer rainy season every other year.

Our results confirm that the composite technique should not be used to create fecal NIRS diet proportion calibrations. Although determination of the numerical proportion of grass in elk diets was not successful, discrimination of relative proportions (i.e. high, moderate, low) was moderately successful. Perhaps with greater number of samples and a greater range of values, this discrimination would prove stronger. Even if only useful as a screening tool, this type of analysis, along with diet or fecal constituent predictions, could provide useful information to wildlife or livestock managers interested in assessing potential diet overlap or nutritional status of wild versus domestic ungulate herbivores. Portable NIRS has been applied to discriminate between[6] or predict chemical characteristics[6] of livestock feces. Further development of a portable technique in the field in real-time would greatly enhance the applicability of fecal NIRS in nutritional management of free-ranging herbivores.

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