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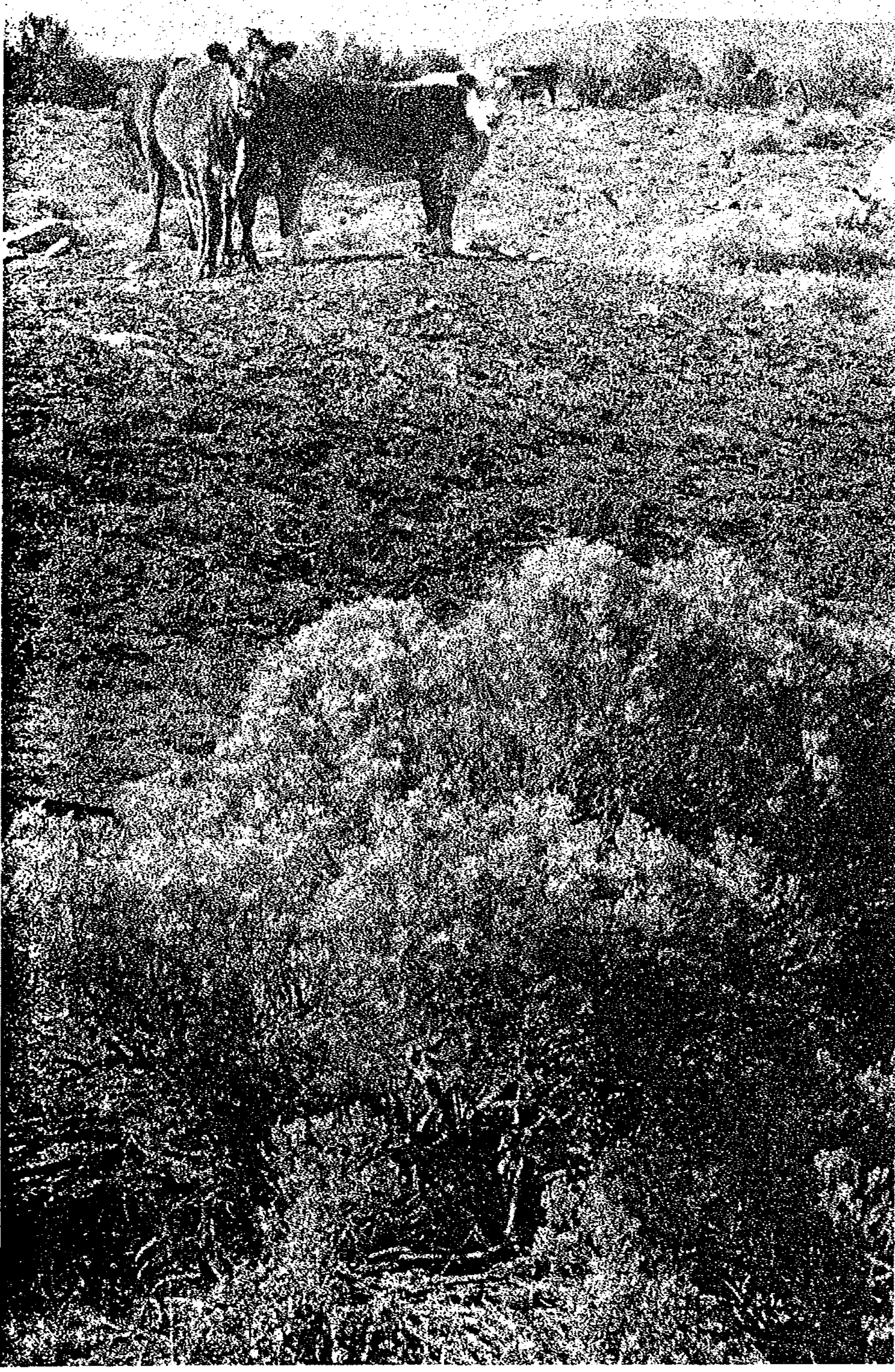

EFFECTS OF A SAVORY GRAZING METHOD ON BIG GAME

A Final Report

RICHARD L. BROWN

September 1990

FEDERAL AID IN WILDLIFE RESTORATION PROJECT

Arizona Game and Fish Department Mission

To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft recreation for the enjoyment, appreciation, and use of present and future generations.

Arizona Game and Fish Department
Research Branch

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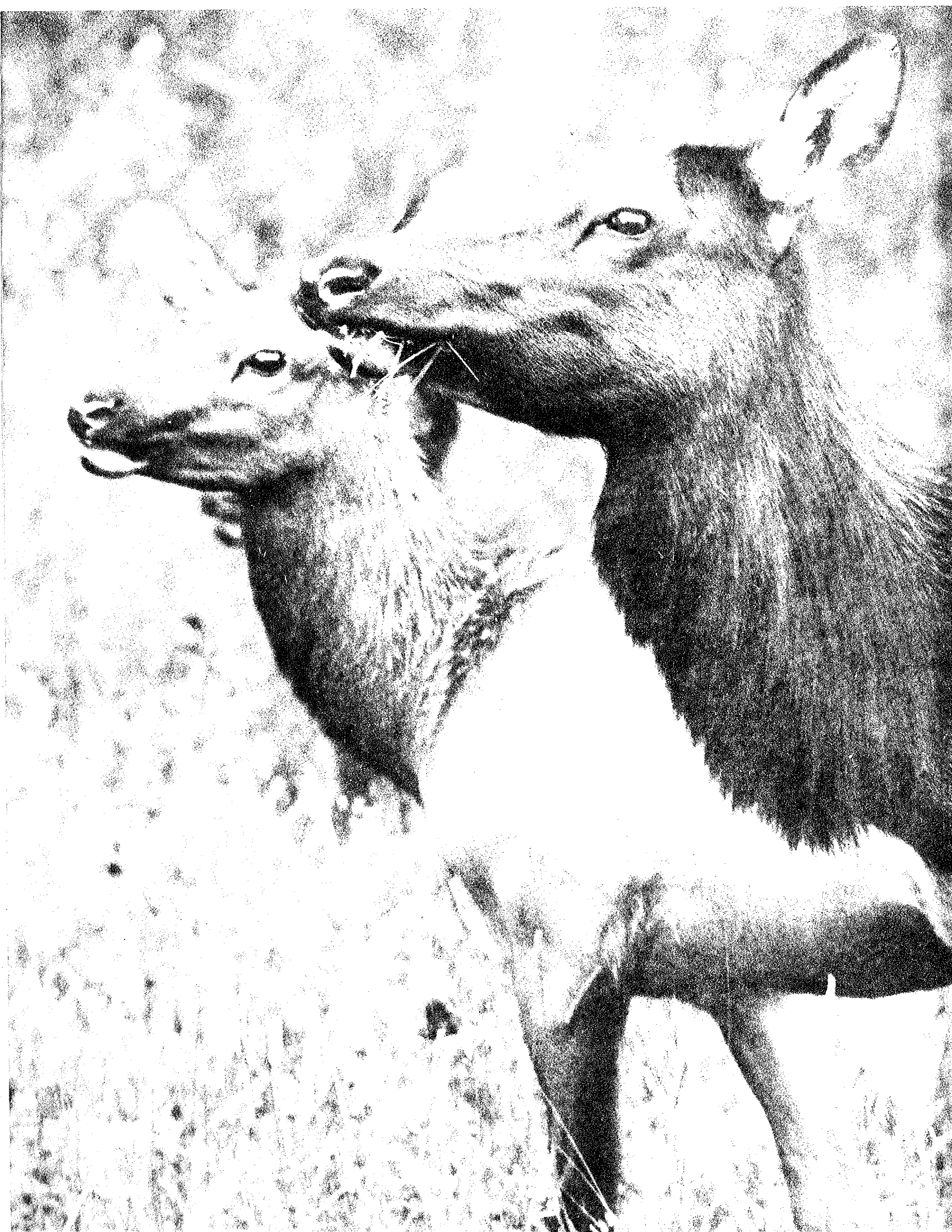

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Effects of a Savory Grazing Method on Big Game

Richard L. Brown

Abstract: Elk, mule deer, and pronghorn antelope use levels were monitored within a radial design holistic resource management cell, and an adjacent set of rest-rotation pastures that were grazed by cattle during the summer months. The cell's internal fences (two-strand electric) created no discernible problems relating to hunter access, hunt quality, or elk movement patterns. Mule deer and pronghorn densities appeared to remain static throughout the study; however, numbers of those species using the study area were too small to yield reliable conclusions. Initial cattle stocking rates were about double that of previous years. Decreased rainfall and increased cattle numbers initially resulted in poor range conditions; therefore, livestock numbers were progressively reduced because of the declining range condition. Elk populations increased substantially during the course of the study and, combined with cattle grazing, prevented range recovery. There was evidence of elk displacement from the cell to the rest-rotation pastures during years of extremely low food production. A discussion of requirements for effective wildlife goals is included.

INTRODUCTION

Livestock selectivity for flat accessible areas, preferred plant species, and new foliage on recently grazed plants generally has been recognized as a major contributing factor to range deterioration. This problem is particularly acute under continuous grazing systems where deterioration can occur under both light and heavy stocking rates. The heavier the stocking rate, the larger the area of involvement. Subsequently, a variety of deferred rotation systems have been implemented in this country, and elsewhere, in an attempt to evenly distribute use and to provide grazed plants with an adequate rest period before regrazing. Among the more advanced of these is an approach advocated by Hormay (1961, 1970). For the sake of understanding the differences between Rest Rotation Grazing, Short Duration Grazing (SDG), and grazing under the Savory Grazing Method (SGM), it is worthwhile to examine the fundamentals of the Hormay system.

Hormay (1961) advocated concentrating livestock to reduce selectivity in grazing. He stated that "fairly heavy stocking is desirable in rest rotation grazing since it forces greater use of the less palatable forage species and the less accessible grazing areas." He recommended initial target use levels of 66% by weight. Adjustments could be made either up or down from that point depending on animal performance and range condition. The negative effects of heavy stocking could then be offset by adequate rest periods for two purposes: to allow established plants to replenish root reserves and to allow seedlings to become established. Additionally, he recognized the positive effects of removing decadent stems, either through grazing or trampling (not specified), so that new photosynthetic material would receive maximum exposure to sunlight (Hormay 1970). The importance of hoof action was also stressed as a means of drilling seed into the ground. Length of grazing periods for any single pasture ranged from half the grazing season to the full season (which completely encompassed the growth period). The Hormay system therefore could not eliminate selective grazing because new plant growth could be regrazed within a matter of days following the initial grazing. Hormay (1970) stated that undesirable effects to the animals result "from denying them access to regrowth generated in pastures grazed earlier in the year." He further stated that "the prime force employed in this tool (rest-rotation grazing) is resting."

Short Duration Grazing (SDG) is a totally different approach that minimizes the regrazing problem that occurs within any single growing season by imposing strict time controls on the grazing period itself. Basically, this approach involves heavily stocking very small pastures for short periods of time and rotating herds from grazed pastures into rested ones before plants can receive any (or many) additional grazings before having had adequate rest. This concept is not a new one. Heitschmidt and Walker (1983) cite Voisin (1959) as stating that a Scotchman named James Anderson recorded the basic principles of SDG as early as 1777. Voisin (1959) further elaborated on these principles. Goodloe (1969) stated: "Expanding on the work done by Andre Voisin of France, Mr. John Acocks and Mr. and Mrs. O.N. Howell of Hillside Farm, Springfontein South Africa, put into practice what was then called 'Non Selective Grazing.'" Savory (1983) subsequently applied these principles to Rhodesian rangelands—hence the development of Rhodesian SDG, the precursor of the Savory Grazing Method more descriptively known today as Holistic Resource Management (HRM). SGM (or HRM) employs the short duration grazing method. However under HRM, SDG is intended to be used as part of a total land management approach that uses an economically profitable livestock operation as a tool to produce some predetermined effect on the land.

Strictly from the stocking and rotation standpoint, heavy concentrations of animals are allowed to graze small restricted areas for very short periods, frequently less than 5 days. They are then moved to another restricted area that has had adequate rest since its last grazing. Ideally, this rotation occurs before any recently grazed plant has attained sufficient height to enable it to be grazed a second time without rest. This rotation method is more accurately described as time-controlled grazing, not just grazing for short periods of time. During periods of rapid plant growth, rotations must be faster (i.e., grazing periods for each pasture shorter) than during periods of slow growth.

Savory (1983) did not intend this method to be practiced as a nonselective form of grazing. Leaving animals too long in a highly competitive situation will result in a loss in individual animal production (Kelton 1978). Nevertheless it appears that the potential for periodic effective use in a nonselective manner does exist. There is a tendency for stock first entering a pasture (paddock) to work from one end of the enclosure to the other, taking only the most desirable plants. Theoretically this does not place those plants at a disadvantage in competing with other species, providing that a second grazing does not occur before regrowth and replenishing root reserves. If the stock is moved at that point, grazing is selective for species but evenly distributed over the area. If, however, animals are forced to remain in the same paddock and retrace their route through it, less desirable plants are used. The method then begins to become nonselective, and if this approach is used in all paddocks over an extended period, at some point a drop in animal performance (weight gains, weaning weights, conception rates, etc.) will occur.

In either case, somewhat higher forage use levels than those encountered under conventional rest-rotation grazing probably can be anticipated simply because stocking rates should be high enough to produce desired animal impact or herd effect (trampling). This herd effect physically breaks down dead plant material and drills the mulch and dung into the topsoil, thus improving the water cycle by increasing the infiltration rate and decreasing runoff. In theory, the HRM approach to livestock management enables the operator to produce and/or maintain any desired plant-successional stage and at the same time improve the water and nutrient cycle. There is some controversy on the effects of hoof action, however; one study (McCalla et al. 1984) has shown that infiltration rates begin to decline within 6 to 8 months in short-grass and mid-grass communities, respectively, under an SDG system using double the recommended stocking level. The test area used simulated one pasture under a one-herd grazing for 4 days per paddock during a 50-day graze/rest cycle. The soils were described as Tarrant Silty clays.

Livestock are usually confined by a radial fencing design resembling a wagon wheel. Fence lines corresponding to the "spokes" of the wheel form the interior paddocks within the overall cell. According to Savory and Parsons (1980), this fencing configuration initially was designed to reduce the stress on livestock that is associated with frequent moves. It also facilitates the handling and movement of stock. But, it is not crucial to the HRM grazing method, which could be applied by using herders and no fencing. HRM Short Duration Grazing is based on properly time controlled grazing periods followed by adequate rest—not just short grazing periods and fencing design.

Potentially, HRM can be a powerful land management tool that can improve range condition. However, because heavy stock concentrations and frequently increased numbers of animals are used, the improper application of this method could be quite detrimental. For these reasons, Savory stresses not only close monitoring of range condition but the establishment of specific predetermined "Management Goals" as well. Wildlife may be included in those goals.

During the past few years HRM has attracted a good deal of attention within the ranching community. Many southwestern range units need improvement. Conventional means of improvement are costly and usually require reduced stocking rates. HRM proposes to improve range condition with minimal capital outlay while actually increasing stocking rates. Some operators have reported improved range condition under a doubling of their previous stocking level (The Savory Letter: Oct. 1985, No. 10, pp. 8-9; July 1984, No. 5, p.6: Apr. 1984, No. 2, p.6).

If HRM proves to be an effective range management tool and becomes used more widely within Arizona, its potential impacts on wildlife must be understood. Higher forage use levels, increased cattle numbers, and high-intensity fencing could have negative effects on certain wildlife species. When an HRM cell was installed in the Quayle-Red Hill area, 14.5 km northeast of Blue Ridge Ranger Station, an investigation was begun into the effects of this grazing method on elk (*Cervus elaphus*), pronghorn antelope (*Antilocapra americana*), and mule deer (*Odocoileus hemionus*) populations, as well as the effects on hunter access into the area. The primary study objective was to evaluate the comparative effects of an HRM application and a standard rest-rotation grazing application on big game population levels.

STUDY AREA

The Quayle HRM cell is located on the Bar T Bar grazing allotments, approximately 15 km (9 mi) northeast of the Blue Ridge Ranger Station, Coconino County, Arizona (Fig. 1). Altitude ranged from approximately 1,890 m (6,200 ft) on the north to 2,000 m (6,562 ft) on the south edge of the cell. The soils are classified as Winona gravelly loam on slopes of 0-10% and Tortugas very stony loam on slopes of 0-30% (USDA 1974). The general area is predominantly a *Pinus edulis/ Juniperus utahensis* and *J. monosperma* (P/J), blue grama (*Bouteloua gracilis*) association. Through the efforts of the Bar T Bar Ranch Co., approximately 3,240 ha (8,000 acres, A) of the cell's interior was subjected to piñon/ juniper chaining and grass reseeding during the 1953-60 period. Considerably higher concentrations of cliffrose (*Cowania mexicana*), mountain mahogany (*Cercocarpus montanus*), and algerita (*Berberis freemontii*) occur inside the cell than in immediately adjacent areas.

Major cool season grasses within the cell are crested wheatgrass (*Agropyron desertõrum*), intermediate wheatgrass (*A. intermedium*), western wheatgrass (*A. smithii*), squirreltail (*Sitanion hystrix*), rye (*Elymus spp.*), Junegrass (*Koeleria cristata*), needle and thread grass (*Stipa comata*), and cheatgrass (*Bromus tectorium*). Major warm season grasses are blue grama, side-oats grama (*B. curtipendula*), little bluestem (*Andropogon scoparius*), and galleta (*Hilaria jamesii*). The usual growth period for cool season grasses is from about mid-February through about the first of June; warm season species from July through mid-September. The most rapid growth for cool season species occurs from mid-April through mid-May, warm season species between mid-July and mid-August.

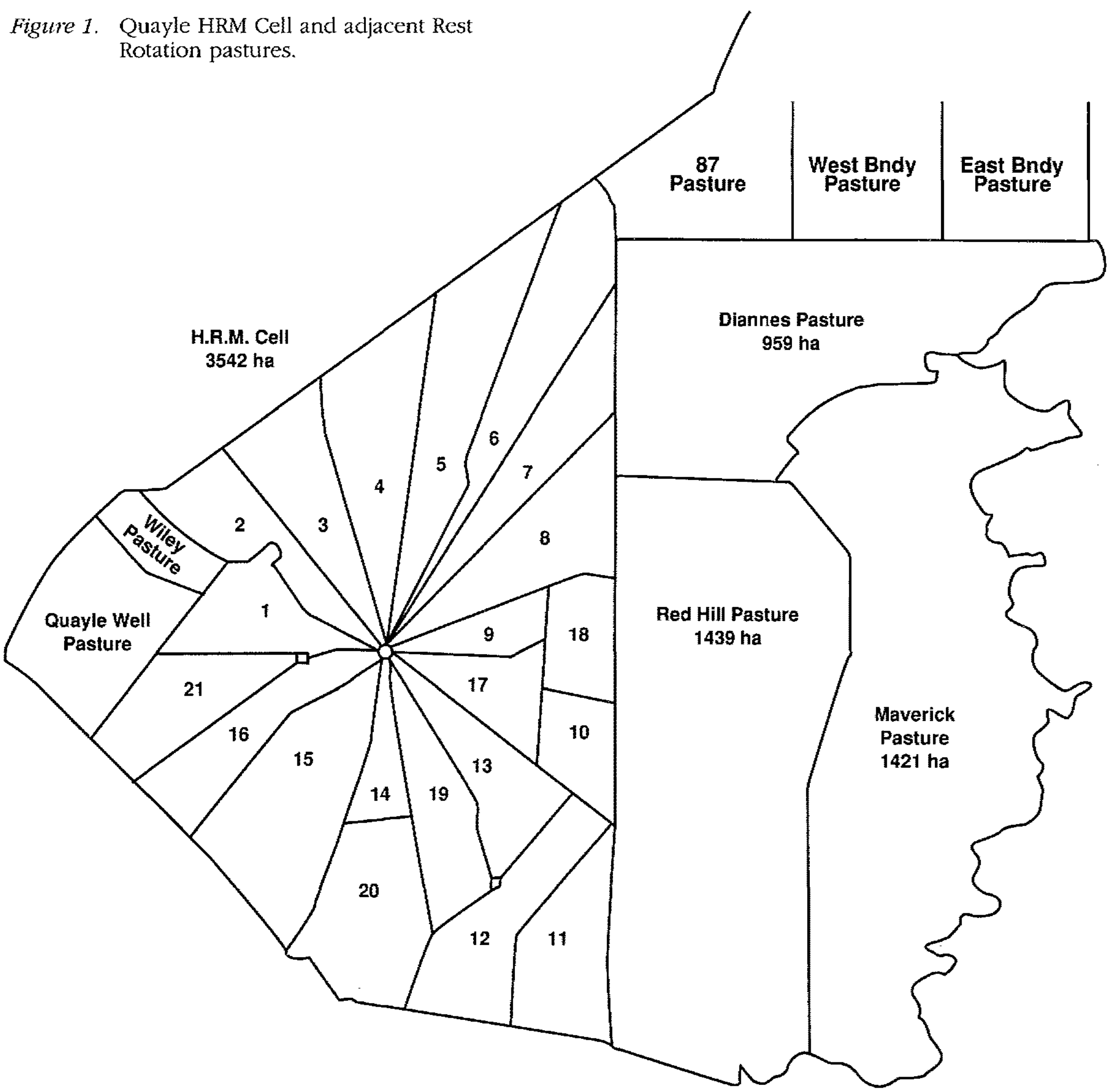
Annual precipitation at Blue Ridge, Arizona averaged 51.6 cm (20 in) for 1970-1984. Of this, 33% (17.2 cm) fell during January–April and 38% (19.6 cm) during June–September. The study area of the cell received considerably less precipitation than Blue Ridge.

The cell (Fig. 1) encompasses 3,542 ha (13.7 mi²). Originally it was established as a 16-paddock enclosure in 1985 and was modified to a 21-paddock system in 1986, with paddock size ranging from 64.8 to 344 ha, average 168.8 ha (0.65 mi²). The paddocks were arranged radially, with boundary fences radiating from the cell center.

In addition to a central water lot at the hub, 18 water sources (dirt tanks or metal drinkers) were distributed throughout the cell. Only about nine of these (Free, Satellite, Payne, Red Hill, and Brown Tanks, Brown, Arizona, and Quayle Wells), and one wildlife watering area provided reliable water sources throughout the summer. Under the 21-paddock system, paddocks 3, 6, 9, 15, and 17 are totally dependent on the water lot at the cell center.

A 4,268-ha, three-pasture rest-rotation system (Diannes, Red Hill, and Maverick pastures), immediately adjacent to the cell on its east side, was established as a control area (Fig. 1). The soil types are the same as those on the cell. Approximately 3,238 ha of the control area rest-rotation pastures were subjected to P/J chaining and reseeding in 1970 by the U.S. Forest Service. This pasture system does not have as well developed a browse inclusion as the cell. Grass species represented are the same as that of the cell;

Figure 1. Quayle HRM Cell and adjacent Rest Rotation pastures.



however, cool season species make up a larger percentage of this total grass community. Volume production of warm season species on the rest-rotation pasture is probably about the same as that of the cell (Ken Vensel, pers. commun.)

METHODS

Grazing Strategy and HRM Goals

The first grazing season following the establishment of the HRM cell was 1985. The enclosure was stocked with 625 head of primarily yearling age cattle, which were crossbreeds from a Hereford cow base and Charlet, Brangus, Angus, and Gelvy bulls. The initial grazing season was 165 days, April 15–October 1, with three days of grazing and 42 days of rest per paddock during fast growth periods and six days of grazing and 90 days of rest during slow growth periods. During subsequent years numbers of animals, grazing season date frames, and days of grazing/resting for each paddock were all subjected to various modifications.

The control area pastures to the east of the cell were to hold an additional group of about 300 cattle from May 1 to October 1 or May 15 to October 15. This schedule was intended to produce moderate use levels under a rest-rotation grazing application. This schedule was also modified, and eventually both groups of stock were combined into a single herd.

During the latter portion of the study, the cell was divided into an east half and west half. One half was grazed, the other half was used as a control in an attempt to determine if the succulent regrowth following cattle grazing would be enough of an attractant to significantly alter elk use patterns between the two sides. If so, this might provide a way to manipulate elk grazing patterns within the limits of their established home ranges and also provide insight into the unanswered question of whether the cell had actually attracted elk during the course of the study. Attractant as used here is defined as causing the elk to remain in an area for a prolonged period of time.

Initially, there were no HRM goals for the cell; therefore, the approach was little more than an elaborate SDG system. Early in 1987 the following HRM goals were established.

- *Watershed* - Produce sound stable watersheds through reduced plant pedestaling, removal of oxidized feed, initiation of interspace fill-in, and accumulation of plant litter.
- *Livestock* - Continue aggressive, economically responsible management practices by optimizing production and profit from livestock on a sustained basis.
- *Wildlife* - Increase wildlife diversity, improve antelope fawning cover, and minimize early spring elk overgrazing.
- *Recreation* - Maintain quality of the area for public use.

The wildlife goal was to be accomplished by deferring paddocks 4, 5, 6, and 7 from livestock production during the April 15 to May 31 period, which encompasses the antelope fawning season. It was hoped that these paddocks could provide a desired 51 cm (20 in) of cover during the fawn drop and shortly thereafter. Additionally, the last paddocks to be grazed in the fall would be the last ones to be grazed during the first rotation the following spring. This schedule was intended to provide some degree of rest following winter elk use.

The wildlife goal is a very general one. Under the scrutiny of a wildlife research project this may be acceptable. However, under general management applications, very specific goals (both objectives and methods) should be stated.

Hunter Opinion and Safety

Fencing around the periphery of the cell was the standard five-strand barbed wire type with the bottom wire 46 cm (18 in) above the ground. Internal fencing for the individual paddocks was two-strand electric on fiberglass poles, with the top wire (hot) approximately 86 cm (34 in) above ground level and the second wire (the ground) 15 cm (6 in) below the top strand. Only one paddock at a time was electrically charged. All road and interior fence line junctions were equipped with cattle guards and all cattle guards and gates were posted with electric fence warning signs. The interior fences were energized by a solar panel, a 12- volt battery, and the Shock Tactics brand Model 121 fence controller (5,500 volts, 15 amps., 55 pulses per minute, pulse length less than 3/10,000 seconds. According to the manufacturer (Waterford Corp., Ft. Collins, Colorado), amperage is high enough to produce a substantial and painful shock. However, safety is attained by keeping the pulse length short (0.0003 sec). The "off time" of almost 1 second allows the recipient to disengage itself from the fence.

The effects of the cell's physical structures on hunter access, attitudes, and safety were of concern. Hunters were interviewed at check points during the 1985 elk and antelope hunting seasons regarding their opinions on the above cited factors. One local physician was also interviewed at the outset of the study regarding potential shock hazard to humans.

Effects of Fencing on Movements of Game Animals

Direct visual observations of game animals close to the interior fencelines were made in conjunction with other activities as opportunities were presented.

Dietary Composition and Overlap for Elk and Cattle

In 1984, 22 fecal pellet transects, running between the cell's east-west boundaries, were installed and three more were installed in 1985. Each transect consisted of a line of circular plots encompassing an area of 10 m^2 (0.0025 A) each, 1.8 m (5.9 ft) in radius. All plots along a transect were approximately 20 m (66 ft) apart. The transects, which ran east to west, were randomly spaced from north to south within equally spaced blocks to provide representative sampling. This spacing yielded 2,137 plots over the entire cell (3,542 ha). Twenty of the transects were established early enough in 1984 to provide one year of winter accumulation pretreatment data.

The rest-rotation pastures originally were monitored using 27 short-pellet transects (108, 10 m^2 plots). At the end of the 1986 summer, this sampling system was expanded to 126 plots encompassing 20 m^2 (0.005 A), 2.5 m (8.3 ft) in radius.

Two elk fecal samples (one summer, one winter) and one cattle sample (summer) were collected at the start of the study in 1986 for diet analysis. A similar collection was made near the end of the study in 1989. Five pellets were collected from each pellet group occurring on 2,137 circular plots (10 m^2) within the HRM cell. All pellets from a given season were combined into one sample.

The seasonal composite fecal material was analyzed for species composition by microhistological techniques at the University of Arizona, Tucson. All pellets within a sample were hydrated and thoroughly blended. Five microscopic slides were selected randomly and prepared from the slurry. Frequency of occurrence of each species was estimated for each slide. Overall species composition of the sample was determined by summing frequencies across slides and computing the proportion of the total that consisted of a particular species.

Degree of dietary overlap between cattle and elk was calculated according to Horn's modification of Morista's measure of niche overlap (Horn 1966); following a review by Smith and Zaret (1982). Dietary overlap was determined for each season from which fecal samples were collected.

Seasonal Habitat Use

All transect plots (n = 2,137), discussed above, were classified according to their dominant vegetational and physiographic characteristics. The frequency that plots occurred was tabulated by strata of vegetation and physiography. These values then, are estimations of the proportion of the HRM cell that was composed of each stratum and, consequently, represent the availability of those habitat components to the animals, within the context of the HRM cell.

Pellet accumulation data were used to stratify plots into high, low, and no use categories. The number of pellet groups found in each circular plot was divided by the number of days in the accumulation period, to yield a rate of deposition per unit area. A conversion to the deposition rate was necessary to standardize data for comparisons. The frequency distribution of deposition rates was then examined for naturally occurring break points and, subsequently, was divided into high, low, and no use strata.

Habitat use was evaluated by tabulating the frequency of plots occurring within use categories by habitat categories. The expected distribution of these two-way tables was the marginal totals, which represented the proportions of those habitat types available. The chi-square goodness-of-fit test was used to compare observed (used) versus expected (available) frequency distributions. A significant difference ($P \leq 0.01$) indicated that the animal did not use each habitat category in proportion to its availability.

Thomas and Taylor (1990) cautioned against the use of the chi-square goodness-of-fit test where both used and available distributions are estimates, unless the estimates of available were derived from a large sample. The sample size of 2,137 plots used here is believed to be sufficiently large enough for this study area to nearly equal habitat mapping.

If a used distribution was significantly different from available, then the two-way tables were examined for trends indicating avoidance or selection. For example, if the number of plots not used was less than expected, and the number of plots used increased with increasing degree of use, then a trend toward selection was indicated for that category. To better evaluate the relative selection or avoidance, Jacobs' D was calculated for each category.

Jacobs' modification of Ivlev's Electivity Index (Jacobs 1974), referred to here as Jacobs' D, is a standardized ratio of use to availability that ranges from –1 to +1. If, for example, very few plots were classified as category K, and a large number of plots that were used contained K, then D would approach +1, thus indicating strong selection. Values approaching zero indicate use as available. To simplify calculations, low and high use categories were combined.

Lastly, simultaneous Bonferroni confidence intervals (90%) were calculated for the difference between the frequency of used and available plots for each habitat category (Marcum and Loftsgaarden 1980). These confidence intervals were calculated only for those distributions yielding a significant chi-square value. If the confidence interval for a given habitat category did not include zero, then the degree of use of that habitat category was significantly different from available. All of the above analyses were used jointly to assess selection.

Forage Quality, Quantity, and Use

The U.S. Forest Service monitored precipitation, plant condition, and forage use levels annually from 1985 to 1988 (Vensel and Mundel 1990). Various data sets from those assessments were reviewed and are included, in part, in this report. These data were related to results of this study where applicable.

Monthly samples of fresh elk fecal pellets (five pellets from each of 15 pellet groups) were collected during the October through April period across all years of the study. These were analyzed for diaminopimelic acid (DAPA) content to determine if this amino acid declined across years. Nelson and Davitt (1984) reported that DAPA may reflect dietary quality. DAPA is an inclusion in the cell walls of rumen bacteria that is not destroyed by the digestive process. Theoretically, the higher the plane of nutrition, the greater the amount of rumen activity and, subsequently, the greater the DAPA content in fecal material. Analysis of variance was used to determine if DAPA content significantly changed over time.

Additionally, species composition of the diet was examined to determine if diet composition changed between the start and end of the study. Any change in diet composition was evaluated to assess potential relationships to the HRM grazing method.

Elk, Mule Deer, Pronghorn Antelope, and Cattle Density

Population trends for big game animals were monitored by fecal pellet accumulations (Smith 1964, and Neff et al. 1965). By determining the density of fecal pellet groups over a known period of time and area, and by knowing the average daily defecation rate of an animal, then the number of animals occupying a given area during a given time may be calculated.

Pellet plots were read and cleared twice annually, just before April 15 and just after September 15. This schedule yielded two sets of readings per year, one reflecting winter use levels and the other summer use. A group of pellets was counted only if the number of pellets exceeded 50 for elk and 30 for deer, and if more than half of those fell within the outer boundary of the plot. Specification of a minimum number prevented the inclusion of partial defecations and scattered pellets.

Elk, mule deer, pronghorn, and cattle droppings were recorded during these counts. Neff (unpublished data) attempted to develop discriminating criteria based on the pH value of deer and pronghorn pellets. The overlap in pH ranges was such that the technique was unsuccessful. Pellet counts of deer and pronghorn were henceforth combined. Records of annual cattle stocking rates and grazing schedules were obtained from the Bar T Bar Ranch Co.

Numbers of elk, mule deer, pronghorn antelope, and cattle were determined, as well as time of occupancy. From this information, and an estimate of the comparable foraging capacity of elk in relation to cattle, the relative grazing pressure of both species was calculated as animal unit months (AUM).

Observations of grazed plants, made by USFS and Bar T Bar Ranch personnel throughout the study, suggested that elk were selecting the areas most recently grazed by cattle for their own feeding activities. The experimental design of this study was altered in light of those observations and by several pieces of recent literature, which are summarized below.

Elk selectivity for new vegetative growth, over more mature foliage, has been recognized by previous investigators. Rodiek and Delguidice (1982) documented a significant shift in elk use of clearings in early spring to the use of forested areas in late spring and summer. They attributed this shift to the availability of more digestible forage that was in an earlier phenological stage and occurred in partially shaded areas under forest canopies. Nelson and Leege (1982) stated that "elk diet gradually shifts from one group of plants to another as they appear in phenological sequence."

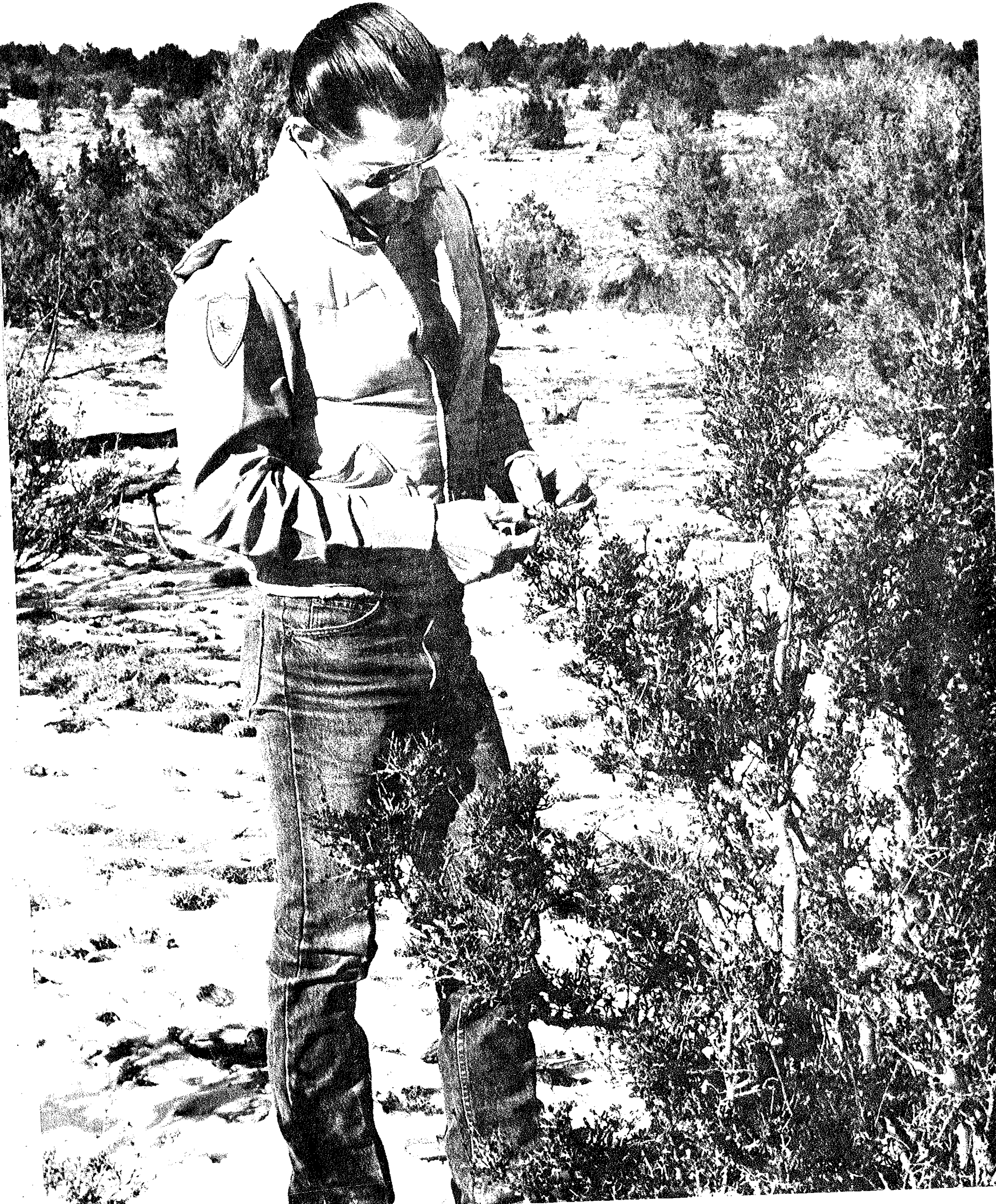
A northeastern Oregon study by Anderson and Scherzinger (1975) suggests that May to mid-June cattle grazing, at what appeared to be a light to moderate level, significantly increased both use levels and length of use periods by wintering elk. Their explanation involved more than just the removal of stifling "wolfy" vegetation by cattle. They cited Cook (1972), Smith (1966), Lamb (1967) and Salisbury and Ross (1969, p.174 and pp.693-694) in postulating that grazing (like heat or drought) interrupts the growth of a plant at an immature stage and, subsequently, causes certain metabolic changes that make that plant more palatable, drought resistant, and frost resistant. These changes include a movement of water from older to younger tissues thus enabling the latter to grow longer, an increase in bound water and water-holding colloids, a conversion of starch to sugar, and a slowing down or stopping of the movement of assimilates through the cells thereby "fixing" the nutritional quality of green foliage in the mature forage.

In contrast, a Montana study by Dragt and Havstad (1987) showed that a single defoliation event during the summer grazing period produced no noticeable change in the winter chemical composition of three major grass species: Idaho fescue (*Festuca idahoensis*), rough fescue (*F. scabrella*), and bluebunch wheatgrass (*Agropyron spicatum*). They concluded that summer cattle grazing at that level had no effect on the winter nutrient levels in elk forage.

A 3-year study in southeastern Washington by Skovlin et al. (1983) showed that in mid-April through early June moderate-level cattle grazing did not promote increased winter elk use overall and significantly decreased use levels during one of those years. However, there was nothing in the Quayle HRM cell data that suggested negative reaction by wintering elk. And, the indications were that heavy spring/summer cattle use was promoting a flush of new grass growth more attractive to wintering elk than the cured plants in surrounding areas, provided of course that there was enough standing vegetation to attract them.

The initial speculation during this study was that an area grazed late in the summer, and heavily, might attract wintering elk and that early light grazing probably would have no effect. In an attempt to evaluate this supposition, both halves of the cell were to be subjected to an early light graze in 1988. Later in the summer the west half was to be heavily grazed and the east half not grazed. If the west side received an increased level of elk use during the following winter, the roles of the two halves of the cell were to be reversed in 1989 in an attempt to produce a replication.

Following page:
Mountain mahogany showing heavy utilization.



RESULTS

Grazing History

At the outset of the study, based on 1984-85 winter and 1985 summer pellet counts, and an accumulation rate of 12.5 pellet groups/day for elk (Neff et al. 1965) and 13.5 pellet groups/day for mule deer and pronghorn (Rassmussen and Doman 1943, and Smith 1964), the cell held approximately 315 wintering elk, 130 summering elk and about 45 mule deer and pronghorn antelope in combination. Only about 20 of these were believed to be pronghorn. Historically, the area of the cell has held larger numbers of wintering elk than the rest-rotation pastures. Comparative levels of past summer use are not known (Ken Vensel, pers. commun.).

From 1964 through 1984, the Bar T Bar ranch stocked the area now occupied by the cell and control pastures with 700 head of yearling cattle annually (3,500 AUMs). The grazing period was May 1 through September 30 except for 1983 and 1984 when the April 15 through September 30 period was used. During these five month grazing periods, all 700 head occupied the entire cell area for 2.5 months and the area of the control for the remaining 2.5 months. As with most large pastures, distribution was a problem. Average annual use levels were about 35%; however, 32% of the area was receiving greater use whereas 28% of the area was receiving less use. Range conservation officers believed that a classic condition of overgrazing and overrest had developed. On a growing number of sites, neither seedlings nor young perennial grass plants could be found. Vegetative condition was becoming increasingly stagnated, and there was evidence of a decline in plant vigor.

In an attempt to reverse the deteriorating range conditions, HRM principles were incorporated into the Red Hill management plan. The first grazing season following establishment of the cell was 1985 (Appendix 1). During the course of the study the intent was to stock the cell with a main herd of 600 or more animals from about April 15 to September 15 or October 1. The control pastures would hold a separate group of about 300 cattle that would graze each of the rest-rotation pastures for about six weeks during a five month period from May 15 to October 15 or May 1 to October 1.

Adverse climatic factors coupled with heavy stocking rates resulted in short food supplies during the second year of the study. Reduced plant vigor and adverse growing conditions in the following years necessitated reduced grazing schedules (Appendixes 2 and 3).

Hunter Opinion And Safety

Interviews conducted at check points during the 1985 hunts failed to detect any serious problems associated with hunter access or attitude toward cell structures. Fifty elk, antelope and deer hunting parties were asked if they had any difficulty in travel or access on the cell. Forty-eight answered "no." Two answered "yes" but the difficulties they encountered were related to rough or muddy roads and not fence lines. The nature of the fences allows them to be pressed to the ground to allow crossing without any damage to the fence. The check station was discontinued after the first year.

According to Dr. Michael J. Keberlein, M.D., a Flagstaff physician, "Users of modern heart pacemakers (installed within about the last 10 years) are not threatened by contact with electric fences" but "wearers of earlier models might be subject to some risk" (Neff 1985). This seems to be the only unique and serious threat that electric fences pose to humans.

Effects of Fencing on Movements of Game Animals

Because of the low density of animals summering on the cell, direct visual observations of big game reactions to the fence lines and cattle concentrations were difficult to obtain. However, 13 observations of game animals near fence lines were made (Appendix 4). All species (elk, pronghorn and mule deer) were observed crossing the electric fences by going both over and under the wire. In only three cases did animals parallel or fail to cross the fence lines. This is certainly no more than would be expected when given the choice of three (and occasionally four) directions to travel.

Winter population trends for these species were either static or increasing during most of the study, which in itself suggests that neither the fence lines nor the density at which they occurred posed any impediment to movement or area used by the species involved. Additionally, although some wire breakage had occurred, it was not nearly as much as he would have anticipated had standard barbed wire been used (Chuck Phillips, Bar T Bar cell manager, pers. commun.).

Diet Composition and Overlap

Dietary analysis revealed several differences between the samples collected at the outset of the study (1985-86) and those collected near its termination (1988-89) (Figs. 2-9).

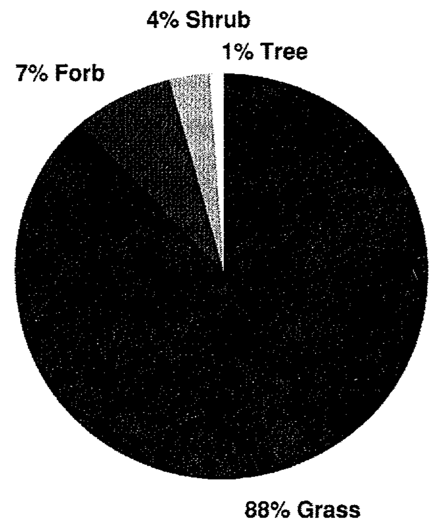


Figure 2. Cattle diet composition on the Quayle HRM cell during the summer of 1985 (percent by class).

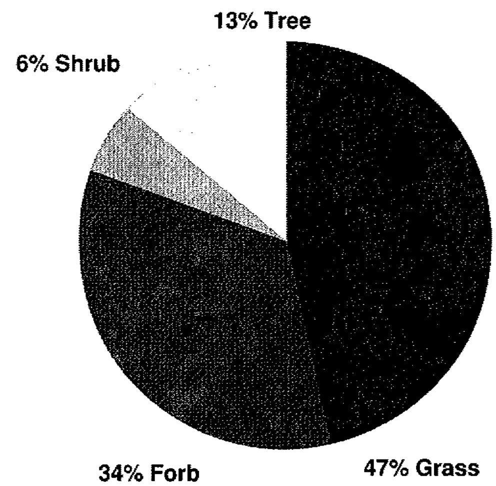


Figure 4. Elk diet composition on the Quayle HRM cell during the summer of 1985 (percent by class).

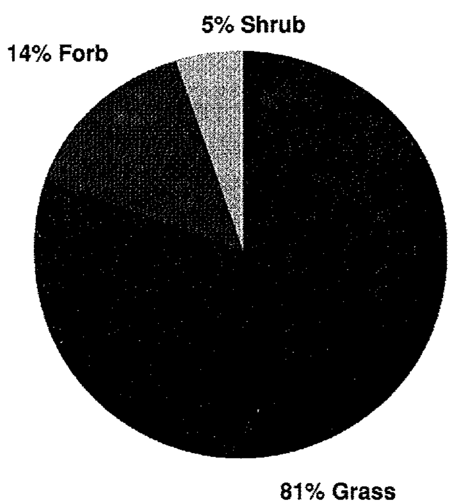


Figure 3. Cattle diet composition on the Quayle HRM cell during the summer of 1989 (percent by class).

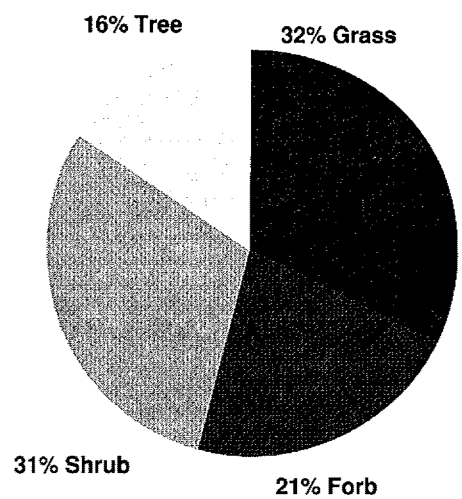


Figure 5. Elk diet composition on the Quayle HRM cell during the summer of 1989 (percent by class).

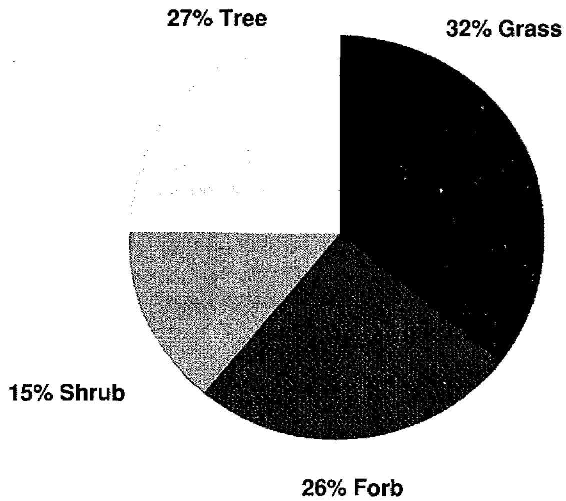


Figure 6. Elk diet composition on the Quayle HRM cell during the winter of 1986 (percent by class).

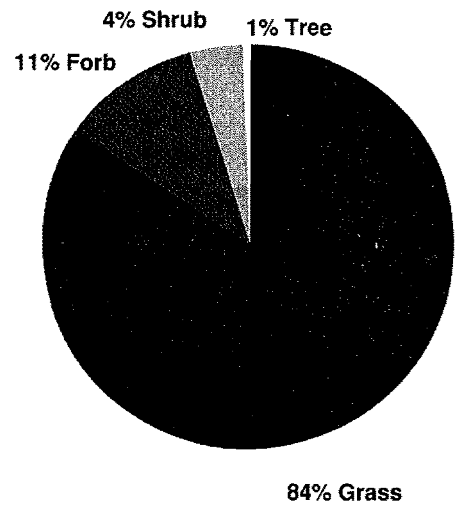


Figure 8. Cattle diet composition on the Quayle HRM cell, all years (1985, 1986, 1989) and seasons combined (percent by class).

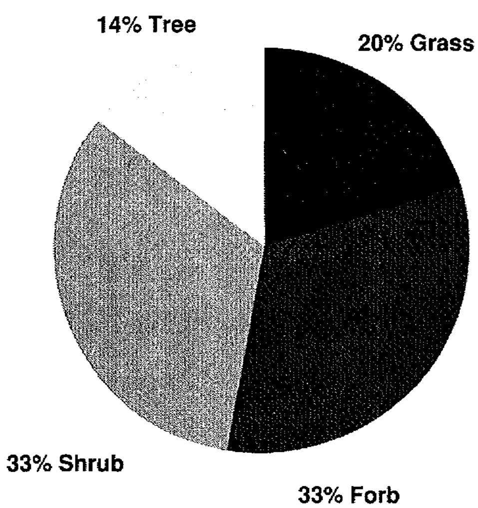


Figure 7. Elk diet composition on the Quayle HRM cell during the winter of 1989 (percent by class).

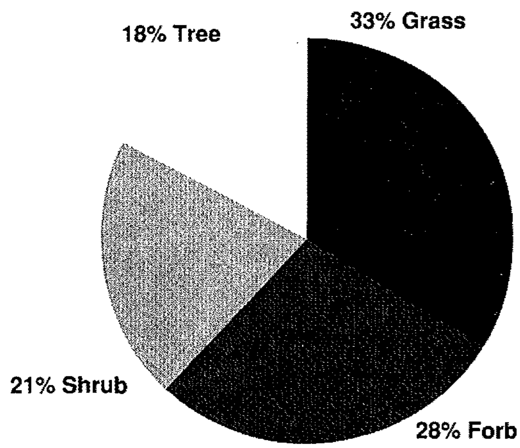


Figure 9. Elk diet composition on the Quayle HRM cell, all years (1985, 1986, 1989) and seasons combined (percent by class).

Grasses constituted 12% less of the elk winter diet in 1988-89 than in 1985-86. Forbs and shrubs combined increased 24.2% (Appendix 5, Figs. 6 and 7). Elk summer diets followed a similar pattern with grass representation declining 13.5% from 1985 to 1989, while shrubs and forbs combined increased 12.1% (Appendix 6, Figs. 4 and 5). Despite the very limited grazing schedule in 1989, grass representation in cattle summer diets had decreased 7.0% and the number of grass species consumed nearly doubled. Use of forbs and shrubs combined increased 5.3% (Appendix 7, Figs. 2 and 3). These trends are consistent with reduced grass forage production levels that were indicated at the end of the study.

To a major degree, elk and cattle used the same plant species but in different proportions (Figs. 8 and 9). The major grass species used by cattle (85%) were *Bouteloua, Agropyron,* and *Hilaria jamesii.* Elk use (33%) was primarily of the same species plus *Bromus tectorum.* Major forb use was concentrated on *Dalea, sphaeralcea,* and *Marubium* by both cattle (11%) and elk (28%). Shrub species use by elk (21%) was concentrated on *Cercocarpus, Cowania,* and *Artemisia.* Cattle use of shrubs (4%) was very light in comparison. Only two species, *Artemisia* and *Yucca,* ever composed more than 1% of the cattle diet. *Cowania* was not represented and *Cercocarpus* constituted only 0.5%. By comparison, these latter two genera composed 11% and 15%, respectively, of the summer elk diet in 1989. *Juniperus* spp. and *Quercus* spp. were used by both animals, but to a larger extent by elk (18%) than cattle (<1%).

Morista's overlap index C_i, as modified by Horn (1966), yielded a year round value of 0.65 considering all data combined (both years). This value may be roughly interpreted as indicating a 65% overlap and a 35% area of nonoverlap. Elk and cattle summer overlap values decreased from 0.76 in 1985 to 0.65 in 1989. This was due to a greater shift on the part of elk toward forbs and shrubs and away from grass.

Seasonal Habitat Use

Initial pellet clearing at the time of transect installation provided a fecal accumulation count for both elk and cattle across several years and all seasons. Before installation of the cell structures, cattle used northern portions of the cell more, whereas elk used southern

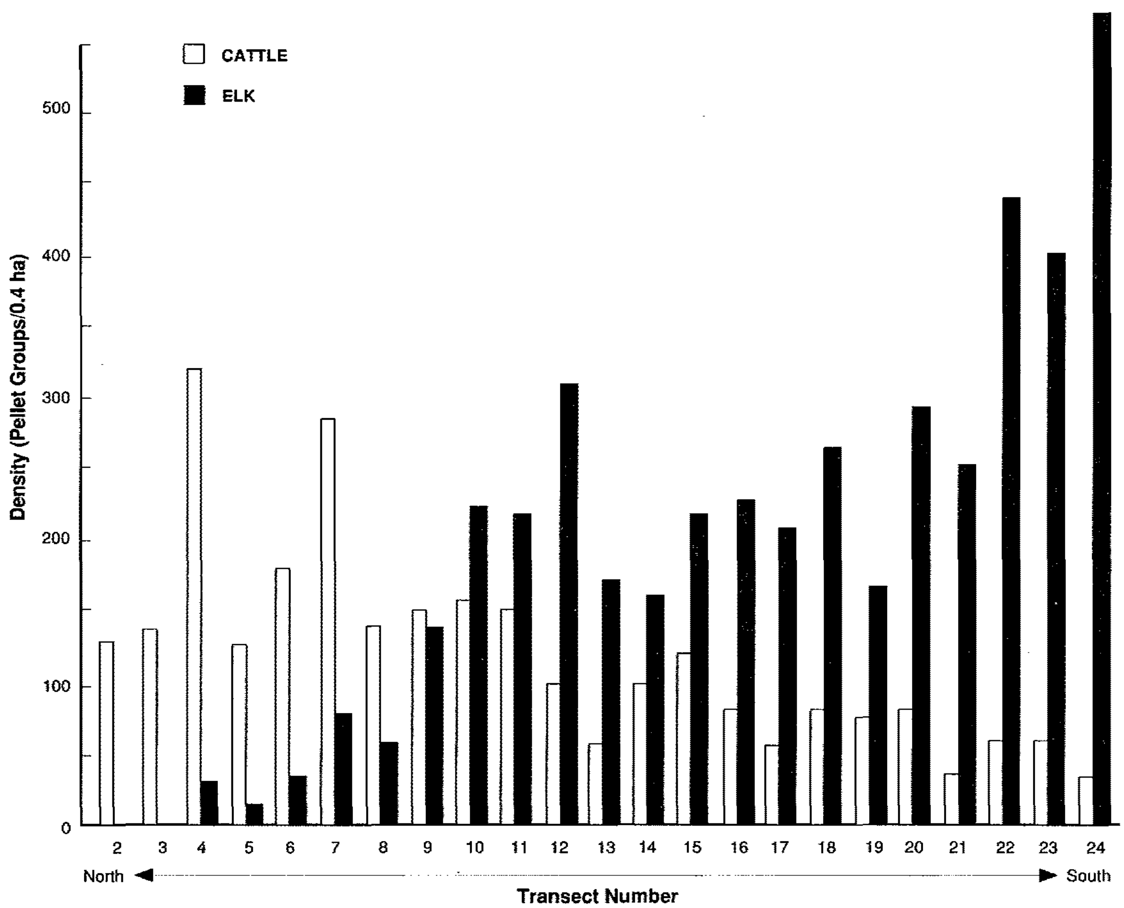


Figure 10. Distribution of cattle and elk pellet groups, Quayle SGM Cell, pretreatment totals.

portions more (Fig. 10). Southern portions of the cell possess more broken terrain and are closer to continuous heavily wooded areas, thus providing greater cover and shrub forage for elk. Northern portions of the cell provided open grassland and flatter terrain for cattle.

Once the cell was established, cattle were forced to rotate through paddocks. This rotation denied them any selectivity options except for those provided by an individual paddock. The previous pattern of elk use (Fig. 10) persisted throughout the study, with the northernmost transects receiving little or no use.

Throughout the course of the study both cattle and elk demonstrated selection for various habitat components (Appendixes 8 and 9). The maximum/minimum range of Jacobs' D values is quite narrow and near zero, indicating neither strong avoidance nor selection in most cases. Nevertheless, certain patterns seem to be evident after examining trends in crosstabulations, D values, and differences.

Cattle selected flatter terrain and gentler topography, whereas elk did not. They demonstrated no selection for aspect. Cattle selected chained areas fairly strongly over nonchained. Elk selection of chained areas was slight in the winter and no selection was evident in the summer.

Cattle strongly avoided piñon/juniper old growth. Elk avoidance of piñon/juniper was less in the winter and no association was detected in the summer (when use occurred exclusively at night). Cattle avoided cliffrose whereas elk showed selectivity for areas with cliffrose and mountain mahogany during both seasons. Mahogany constituted an unknown but extremely small percentage of this association on the cell.

No association between cattle and shrub cover was detected, whereas elk selected for shrub cover levels between 5 and 75% during both seasons. With the exception of rabbitbrush flats, the heaviest shrub cover on the cell occurred in areas that have been chained and are now supporting extensive stands of cliffrose. The association between use levels and shrub height is not clear. Selection for midheight shrubs in the summer undoubtedly is associated with feeding; avoidance of taller shrubs may be due to preference for other areas and the lack of importance of hiding and thermal cover at night. The selection of taller shrubbery in the winter probably is linked to daytime use as hiding cover. Avoidance of low shrubbery during both seasons, particularly summer, is not understood.

Cattle demonstrated a slight selectivity for shrub height less than 61 cm (2 ft), and a slight avoidance for taller shrubbery. Elk showed a slight selectivity for shrubbery greater than 1.5 m (5 ft) in height and a slight avoidance of lower shrubbery in the winter. In the summer they showed a slight selectivity for midrange shrubbery and a slight avoidance of both tall and short shrubbery. Forb and half-shrub cover and dominant species did not show any significant relationships for either cattle or elk.

Cattle selected higher levels of grass cover than elk, but showed no selection for cool versus warm season grasses in the summer. Elk, on the other hand, selected areas with cool season species (wheatgrasses, squirreltail and cheatgrass in aggregate) during both seasons. Because cheatgrass is a decadent item in the summer, it would have contributed nothing to the summer relationship. Squirreltail (*Sitanion*) does not appear on the dietary composition list (Appendixes 5 and 6), thus indicating that the wheatgrasses (*Agropyron*) was the major grass used. Cool season species sustained all of the grazing pressure from the end of February into early or mid-July.

Cattle selectivity for areas with less surface stone and avoidance of areas with more than 25% surface stone was greater than that of elk. Direct visual observation of elk indicated that summertime use of the cell by this species is almost exclusively at night. Daytime bedding occurred in the heavily wooded areas to the south. Winter use on the other hand involved both night use and daytime bedding and feeding. This probably explains their lack of association with P/J old growth during the summer. Likewise, it may explain the lack of correlation with surface stone in the summer because that terrain is used primarily for traveling and feeding at that time of year. Selection for less stony areas in the winter may be due in part to midday bedding activities on the cell. Greater use of east, south, and west slopes in summer may be due to this same area use pattern.

Forage Quality, Quantity, and Use

The following is a synopsis of information on weather patterns (Appendix 10), plant growth and condition (Appendixes 11 and 12), and chronology of events leading up to the present condition on the Quayle HRM cell. The synopsis reflects the periodic conclusions and actions of range conservation personnel assigned to the area. This information was extracted from the U.S. Forest Service draft copy of the Four Year Report On Red Hill Demonstration Grazing Allotment 1985-1988 (Vensel and Mundel 1990), and unpublished reports to the Red Hill Steering Committee during that period.

It should be stressed that use figures from the cell (Appendix 13) cannot be compared with the use level estimates that would be obtained after a rest-rotation grazing period. Under the latter system, varying levels of use occur in a patchy pattern throughout the grazed pasture, depending largely on topography. The relative use of these patches is constant throughout the period. When plants enter dormancy, these patterns are quite obvious, being evidenced by areas with stands of heavy decadent grass cover, other areas with less, and some areas with no standing grass cover. Under an SDG application, regrowth during rest quickly masks the original use pattern in any particular paddock. This procedure will be repeated two or three times during any single grazing season. To give the reader some grasp of what an individual paddock might look like under SDG, Ken Vensel provided his "best guess" at the use levels within the "average paddock" during the first three years at the time livestock were removed from that average paddock (Appendix 14). Use levels are higher on the inner one-third of each paddock because of the existence of the central water lot at the hub of the cell.

1985. Precipitation was not measured because of a broken rain gauge. Spring moisture was more than adequate and continued through mid-May. Summer precipitation was below average with two showers in early July and nothing more until late August.

October plant use studies indicated light overall use, not enough to produce the desired plant and watershed treatments (removal of oxidized feed, reduction of plant pedestaling and eventual reduction of plant interspaces) except at the very center of the cell where animal impact had been the highest. The growth rate of flagged plants indicated that the 30 day rest during fast growth periods should be increased to 42 days. The October plant use study also indicated that "73% of the annual forage was retained, and available for elk or as a drought reserve." Weight gains for yearling steers were above the average of recent years, at 0.9 kg (2.0 lb) per day.

1986. Before cattle entered the cell on April 15 there was concern over heavy early elk use of cool season grass species at the cell center, which had received the heaviest livestock use during the previous fall. Winter elk concentrations left the cell about April 10, and cattle entered the cell April 15, allowing insufficient rest following the elk use. Additionally, the spring soil moisture was insufficient to allow plants to recover from the first livestock graze. Because of food shortages, cattle were removed from the cell in early and mid-August, and placed in the rest-rotation pastures.

Late winter moisture was sufficient to start growth of cool season grasses. However, no precipitation was received in April and only 2.0 cm (0.8 in) in May and June. Adequate moisture for plant growth was not received until August 23. During this period plant growth withered under hot dry winds. Slow plant growth during the May through August period allowed extensive areas to be treated, from the watershed standpoint, by the increased number of cattle grazing in the slow growth mode.

The entire area received a flush of new growth from the late August rains. Elk consumed 10 to 15 cm of regrowth on cool season grasses by the time the October plant use studies were conducted. Again, plants had insufficient time for recovery.

Average daily cattle weight gain was 0.8 kg (1.7 lb) per day, below the 20-year average. However, total production exceeded that during any of the previous years because of higher numbers of livestock.

1987. The spring was cold and dry, and plant response was slow because of a decline in plant vigor. Only 0.8 cm (0.3 in) of precipitation fell in April, and no additional rain was received until mid-July. Only 6.9 cm (2.7 in) fell in July, August, and September combined. Considerable moisture fell in October but was too late to allow the cool season plants to recover.

Elk left the area about April 15, and cattle were brought onto the cell April 15, allowing no time for plant recovery. Early spring elk use occurred on the same areas that received cattle use the previous fall. Concern was expressed over the lack of plant litter in the cell. Consequently, livestock were removed from the cell and placed in the rest-rotation (control) pastures during the first half of July. Elk began returning to the cell in early September, which is several weeks early. This served only to aggravate an already poor situation. Still, cattle weight gains exceeded the long term average of 0.9 kg (2.0 lb) per day.

1988. The winter was mild with a cold snap in April. Only 0.8 cm (0.3 in) of precipitation was received from March through May. Elk left the cell about May 1, 15 days later than usual. Cool season grasses did not recover despite the 3.3 cm (1.3 in) of precipitation in June. The scheduled June 1 "on date" for cattle subsequently was delayed until June 8. Short food supplies on the rest-rotation pastures would not allow a longer delay. A heavy grasshopper infestation occurred at the cell center, and an outbreak of black grass beetles occurred on the southern portions of the cell, as well as at the Red Hill and Maverick pastures. Stock were removed from the entire allotment on July 15. Livestock weight gains were below the 20-year average.

August precipitation of 8.1 cm (3.2 in) allowed some recovery for cool season species, with regrowth of 10 to 15 cm being common. However, elk use of this regrowth was already heavy in October when the plant use studies were conducted. Again, litter was not noticeable and, for the first time, some plant loss was seen around the cell center. Little change in watershed conditions was experienced between 1987 and 1988.

1989. Adverse conditions for plant growth again existed. No USFS summary was issued; thus, detailed information is limited. However, only 0.1 cm (0.04 in) of rain was received up to July 20, and winter concentrations of elk left by April 12 or earlier. An attempt was made to graze the west half of the cell as heavily as possible so that an east half versus west half comparison of elk use levels could be made during the winter of 1989-90.

DAPA Content. Mean winter DAPA values declined slightly across all five years of study (Appendix 15, Fig. 11). However, neither regression analysis ($r^2 = 0.52$, $P = 0.17$) nor an analysis of variance ($P = 0.44$) indicated that there were significant changes. Nevertheless, the three lowest mean values occurred after heavily stocking the cell in 1986 and, in general, occurred following summers when feed was known to have been in short supply.

Elk and Cattle Density

The original intent of this study was to compare a treated area with a control or, in this case, a heavily stocked HRM cell with a lightly stocked rest-rotation system. The need to use the control area to hold cattle during times of short feed exposed the control to somewhat the same treatment as the cell and has therefore compromised the status of the control area to a large degree. It is therefore necessary to explain the sequence of events as they occurred.

Winter Elk Use. Winter elk population levels on the cell, as indicated by fecal deposition rates, increased 13-24% annually (average of 17%) during the first three years of the study (Fig. 12). The net increase for these three years was 58%. This increase was followed by declines of 5 and 23% during the next two years. Net increase across all years, 1984-85 through 1989-90, was 15%.

The winter of 1989-90 was extremely mild. Elk moved to winter range much later than other years, and some may not have

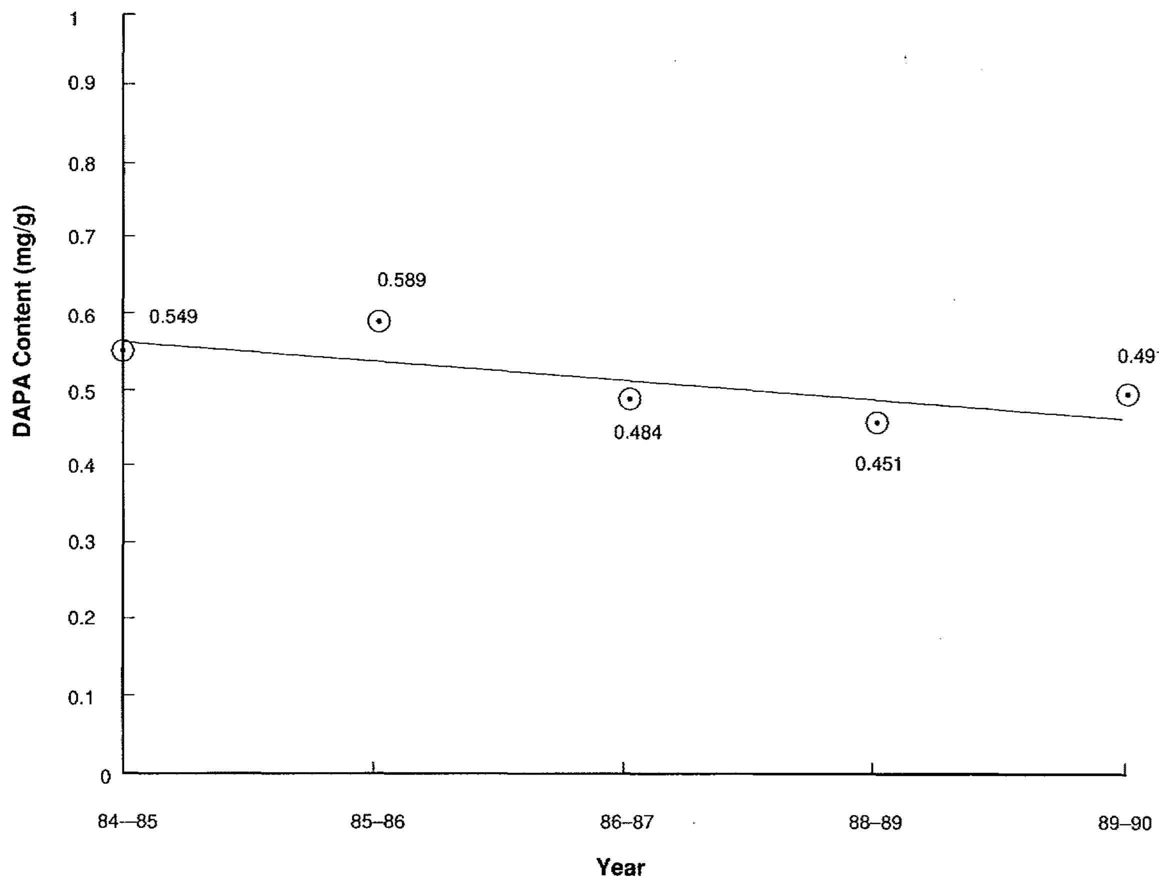


Figure 11. Annual diaminopimelic acid (DAPA) content in elk fecal pellets during five years from 1984-1990. The line indicates DAPA contents regressed on year (r^2=0.52, P=0.17).

migrated at all. This phenomenon was seen throughout the western half of Arizona's elk range. The decline in winter use levels from 1988-89 to 1989-90, for both the cell and rest-rotation pastures, probably was due in part to this factor.

Additionally, game management Unit 5A hunt permit numbers and hunt structure were both modified in 1989. Total hunt permits were increased from 1,065 to 1,125 (Appendix 16). More important however, was an increase from 350 to 525 antlerless permits. Additionally, 100 archery permits were moved into a muzzle loader hunt. These latter two changes, the shift from archery permits to muzzleloader permits and the shift from bull to antlerless permits, would have increased hunter success. As much as 40% of the total game management unit harvest may involve animals associated with the area under study (personal communication with Mark Petersen, Unit 5A Wildlife Manager). Both climate and hunt removal are probably involved in the reduced use level values for the winter of 1989-90.

The hunt schedule for 1988 did not differ from that of the preceding year, however, a 5% decline in elk population trend was documented. It is unlikely that the increase in hunt permit numbers in 1987 and 1988, from that of the 1986 level (55 for the entire game management unit), could have produced any measurable effect on the cell and control area populations.

What appears to have happened from 1987-88 to 1989-90 is that the control pastures supported an increasing proportion of the herd each year (Fig. 12). Figure 13 shows a composite for both areas. Values are simple arithmetic means of each pair of values (cell and control) in Fig. 12. This approach should be appropriate. Even though sampling intensities are not the same on the two areas, they are roughly equal in size. This combination shows a net gain in elk use of 94% from 1985-86 through the 1988-89 period followed by a single 17% decline in 1989-90, which probably can be explained on the basis of a modified hunt structure in conjunction with climatic factors. It is obvious that winter elk use levels increased, both under the short-lived initial experimental design and the subsequent modifications. However, because of the lack of an undisturbed control area, it is unclear whether increases fell short of, equaled, or exceeded the increases in surrounding areas on Arizona's elk range as a whole.

Summer Elk Use. Summer elk population levels (Fig. 14) on the cell and control were much lower than winter levels. Most elk that winter on the cell and adjacent rest-rotation pastures move to the south to higher elevations in the Blue Ridge Reservoir area for summer. Those that do remain drift on and off the area, primarily using the southern portion of the study areas and adjacent areas to the south.

No pretreatment data were obtained for summer use periods. Use levels on the cell exceeded those on the control in 1985 and 1989, but the reverse was true in the interim period. In the first of these three years (1986), food shortages developed on the cell to the

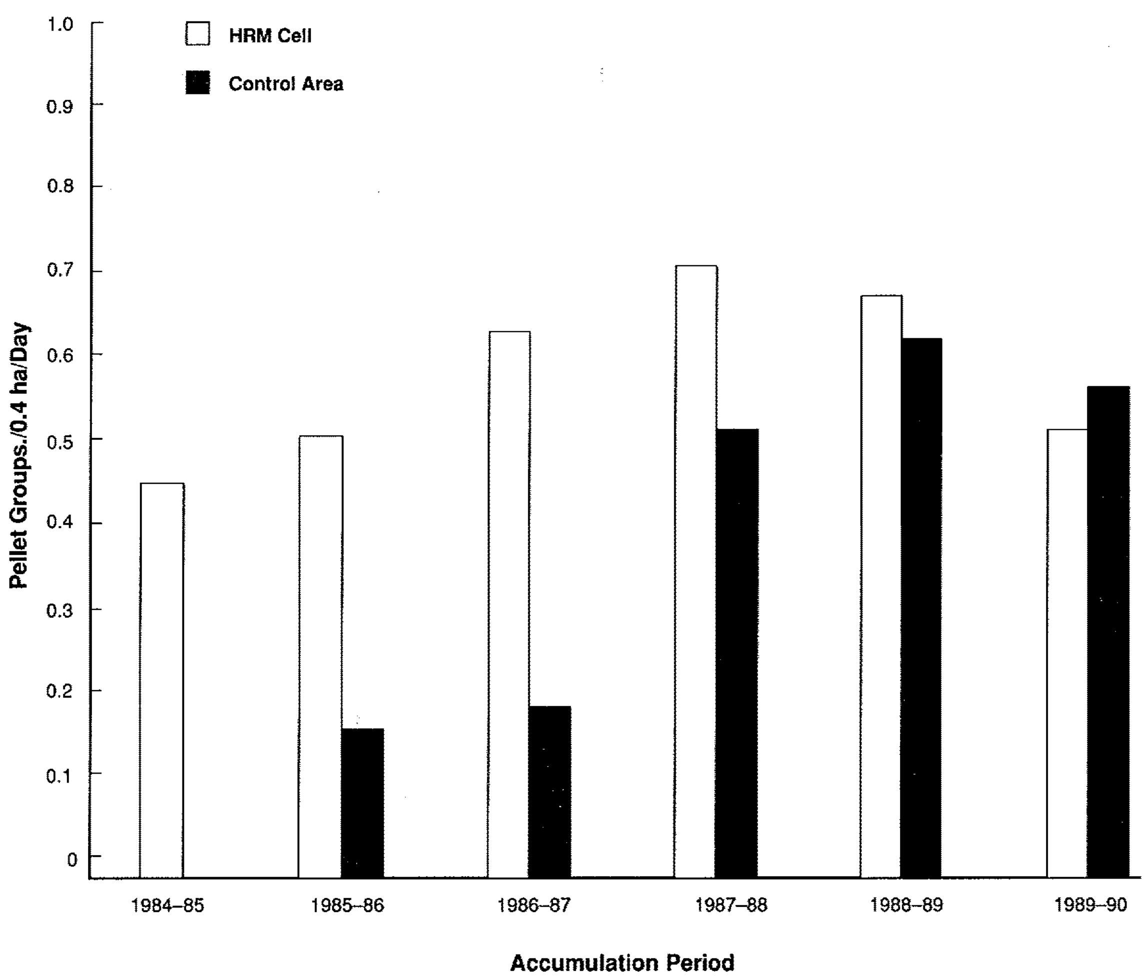


Figure 12. Winter elk population trends.

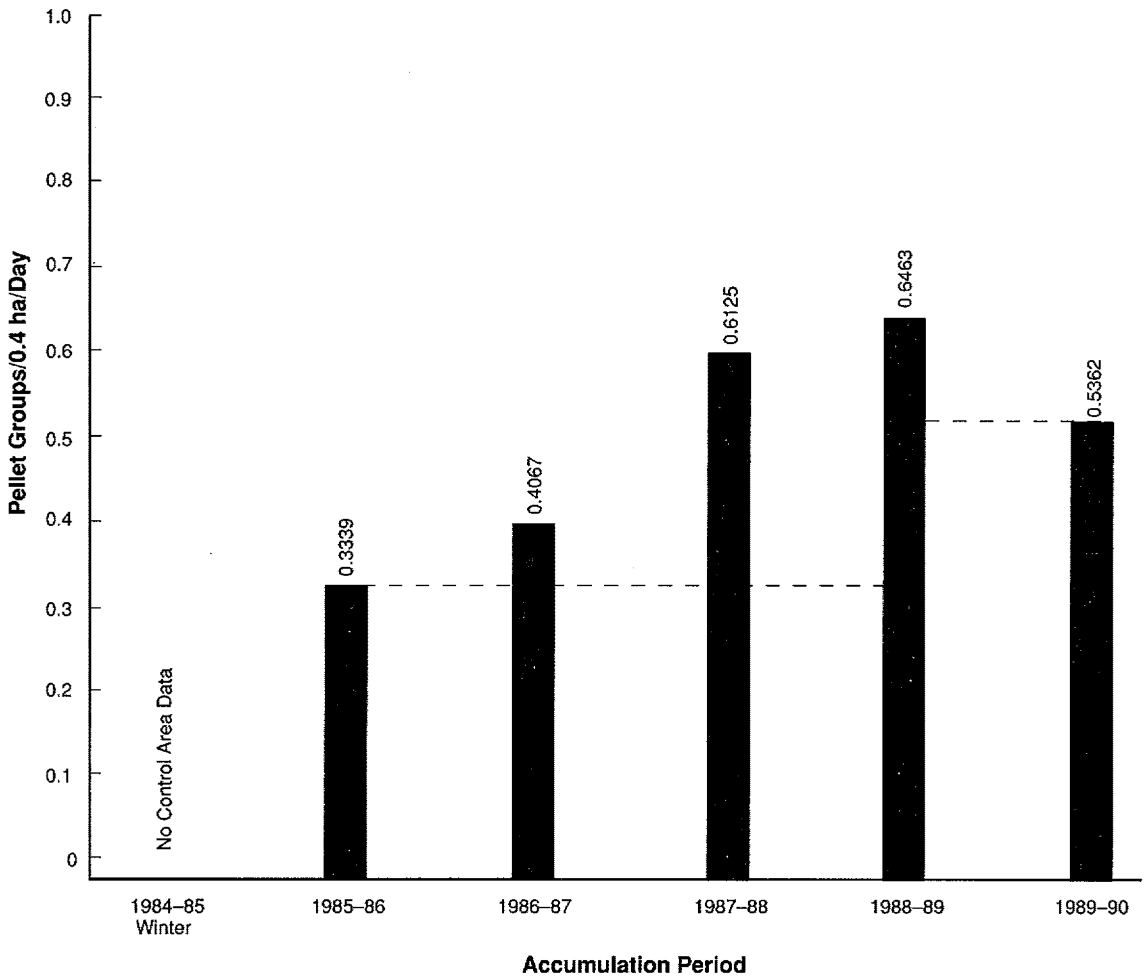


Figure 13. Winter elk population trend; cell and control areas averaged.

degree that the cattle were removed and placed in the control pastures. It is likely that the elk also moved to the control side in search of food. Stock were removed from the cell for the same reason and were placed on the control side at an even earlier date in 1987, and elk may have again done the same. In 1988 all cattle were removed from the entire allotment after grazing the west half of the cell very briefly.

There was no noticeable difference in grass height between the two halves of the cell following the 1988 grazing because little or no regrowth had occurred before or during the grazing period. In 1989 the west side of the cell was again grazed briefly. This regrazing produced a slight difference in appearance between the east and west halves, suggesting that some regrowth had occurred before or during the grazing period. It was in 1989 that summer elk use on the cell exceeded use on the control for the first time since 1985.

Throughout the years when little or no regrowth occurred, the rest-rotation pastures held a certain level of food reserve in the form of standing cured forage that the cell did not have. Displacement of elk from the cell to the rest-rotation pastures during all three years (1986, 1987, and 1988) was probably due to more severe food shortages on the cell than on the rest-rotation pastures.

There is no known explanation for the 1987 higher usage values on both the cell and control. Originally it was thought that late wintering elk had contributed significant pellet depositions to the summer accumulation period. Although this may be true to some degree, the 1988 data values are not as elevated. In addition, late wintering herds were on the study area during pellet clearing operations that year.

Deer And Pronghorn Antelope Use. Mule deer and pronghorn pellets cannot be reliably distinguished and the composite sample is small; therefore no conclusions about the effects of cell management on these species could be made. However, population levels (Appendixes 17 and 18) appeared to have been relatively stable throughout both seasons across all years.

Animal Unit Months: Elk and Cattle.

Year long elk AUM were calculated from the estimated numbers of elk using the study area during a seven month winter and a five month summer period. Elk numbers (Appendix 19) were estimated from pellet group deposition rates, assuming a deposition rate of 12.5 pellet groups per 0.4 ha per day (Neff et al. 1965). Because elk and cattle sizes and diets may differ, the relative amount of grazing that the study area received between years could be evaluated only after the grazing pressure exerted by both species was converted to comparable AUMs (Figs. 15 and 16). To do so, however, a conversion factor was needed to account for those differences.

Lyon and Ward (1982) discuss the conversion of elk AUMs to livestock AUMs. They state that "in standard practices two elk equal one animal unit" for livestock.

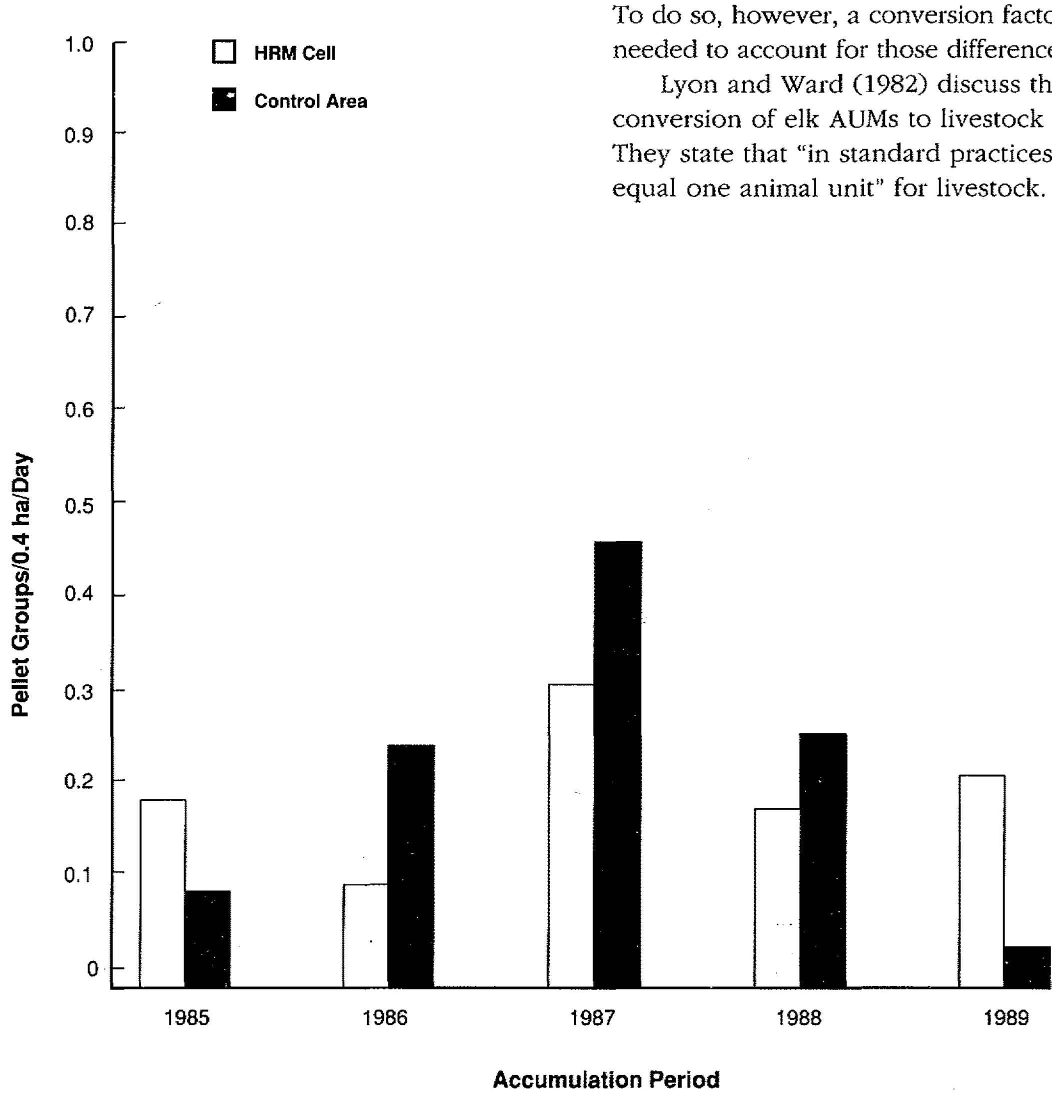


Figure 14. Summer elk population trend.

This latter unit is a 540 kg (1,200 lb) animal unit consisting of a 450 kg (1,000 lb) cow plus a 90 kg (200 lb) calf. Apparently the 2 to 1 conversion factor was based strictly on weight differences. They cited Thorne et al. (1976) as having estimated that dry matter intake by pregnant free-ranging elk was similar to that of cattle under adequate range conditions (22.7 g/kg of body weight/day).

The livestock in this particular study primarily were yearling class animals, weighing slightly less than 230 kg (500 lb) when they were brought onto the study area and about 340 kg (750 lb) when removed. Strictly on the basis of weight, in this case cattle and elk were about equal. However, dietary differences were present.

Elk and cattle weights can be assumed to have been about equal; thus, only the degree of dietary overlap needed to be considered. As discussed previously, dietary overlap between elk and cattle was estimated at 0.65. From this

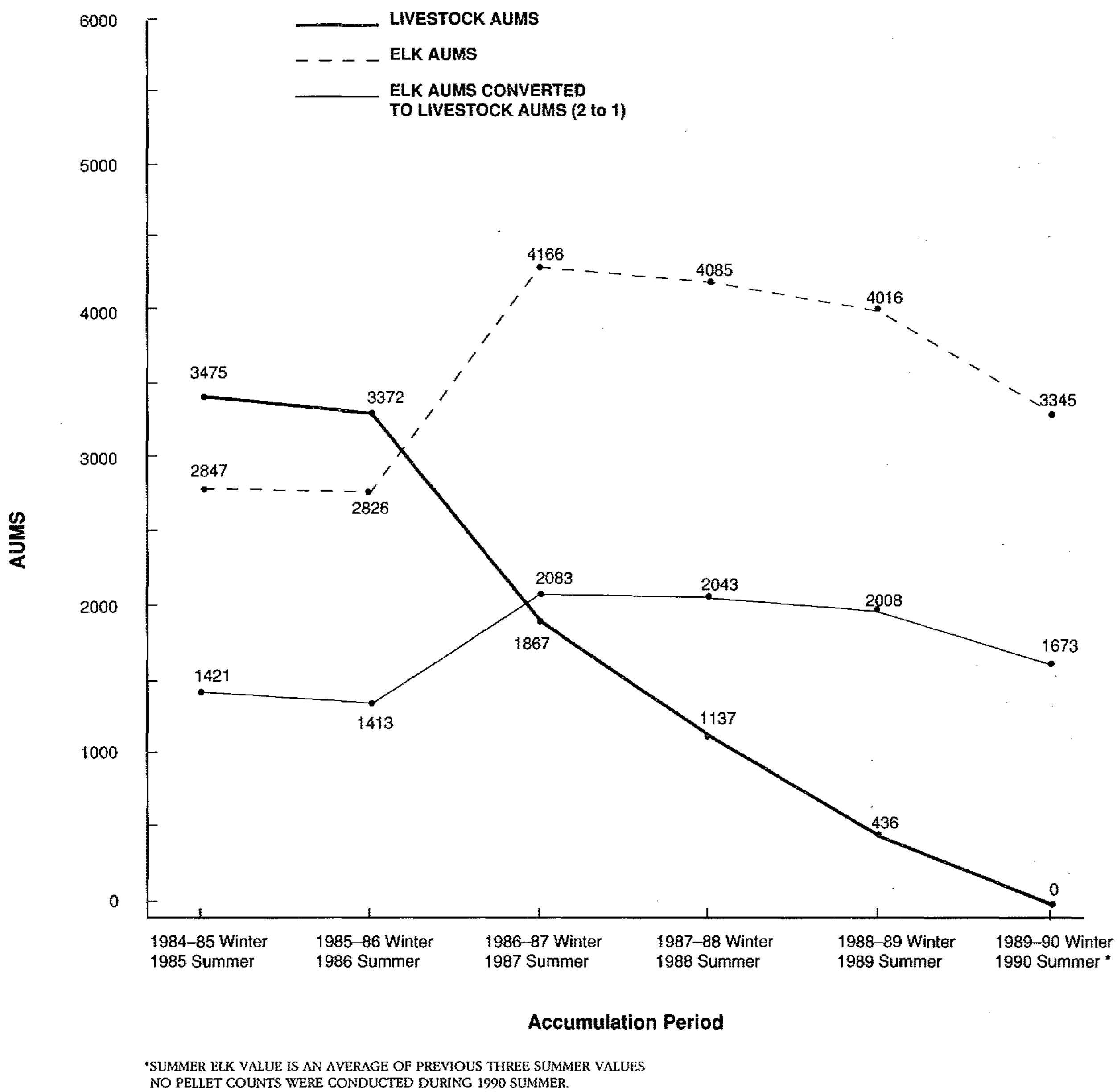


Figure 15. Year long elk and livestock AUMs: Quayle Cell.

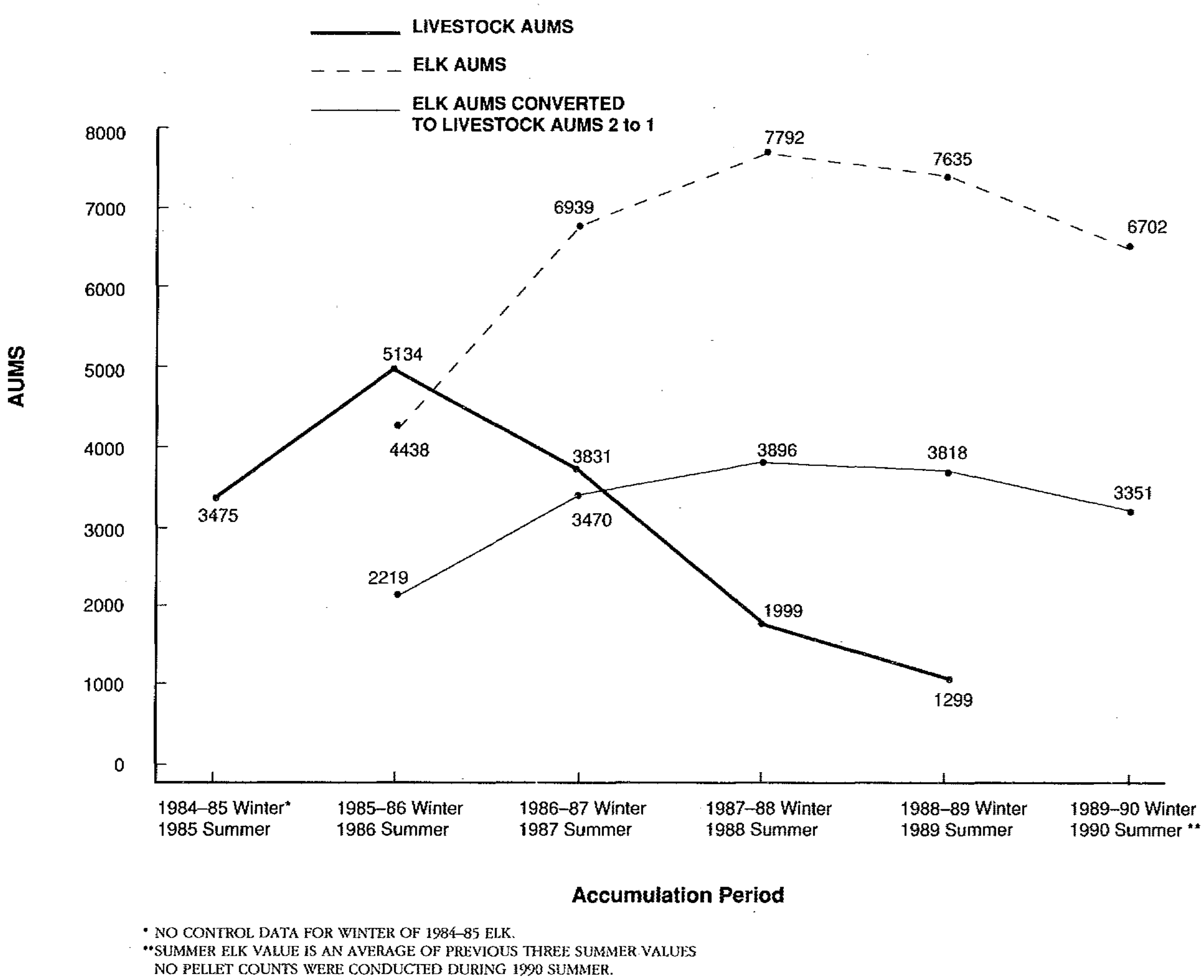


Figure 16. Year long elk and livestock AUMs: cell and rest rotation pastures combined.

value, it is believed that 1.5 elk (1/1.5 = 0.67 ≈ 0.65) would consume equal that of one cow. This would be true because the bovid's diet is homogeneous, consisting primarily of grass and forbs, and that portion of the elk's diet that is not common to cattle is composed of shrub and tree. Consequently, 1.5 elk would be required to consume the grass and forb equal that of one cow.

The two curves graphed for elk in each of Figs. 15 and 16 represent safe upper and lower limits for any conversion of elk AUMs to livestock AUMs. The upper curve is the 1:2 ratio discussed by Lyon and Ward (1982), whereas the lower is a 1:1 ratio. The best estimate of the true value, 1:1.5, lies midway between the two.

Regardless of whether either of the extremes or the midpoint are used, sometime between the winters of 1985-86 and 1986-87 elk AUMs surpassed cattle AUMs on the cell and the same occurred on the cell and rest-rotation pastures combined, less than six months later. By the end of the study, elk AUMs had completely replaced livestock AUMs on the cell and had nearly done the same on the cell and rest-rotation pastures combined.

It must be noted however, that stocking rates on the cell in the first year of the study were nearly double those of previous years, 3,475 AUMs compared to 1,984 AUMs (average for 1974-1984). In 1986, 5,134 AUMs were applied to the cell and rest-rotation pastures combined, compared to a 3,375 AUM average for the 1974-84 period (Appendix 1).

Excessive numbers of cattle in conjunction with adverse conditions for plant growth initiated the range decline. A steadily increasing elk population prevented range recovery following reductions in livestock numbers. Additionally, an integral part of this scenario was lack of adequate rest for the plant community between the time wintering elk herds left the area and cattle were brought on, or vice versa. This factor was not readily quantifiable. Nevertheless, its effect would increase as numbers of either grazing species increased.

The AUM values (Figs. 15 and 16) did not provide as clear an indication of an allowable grazing level as hoped for. Primarily, this obscurity is due to declines in precipitation patterns and plant conditions. For purposes of the following discussion of grazing and plant condition, elk AUMs were converted to livestock AUMs on the basis of a 1:1.5 ratio. These AUM values were added to the cattle AUMs, producing a single value expressing total grazing pressure in terms of livestock forage.

For the cell itself, in the 1984-85 winter plus 1985 summer, 5,611 total AUMs (3,475 livestock and 2,136 converted elk) appeared to have caused no problem. This year received adequate precipitation. During the 1985-86 winter plus 1986 summer 5,492 total AUMs (3,372 livestock and 2,120 elk) were applied to the cell, which was less than intended. A very heavy stocking rate at the outset of the grazing period was reduced in two stages because of lack of forage. One stage occurred in early July, the other in mid-August. This livestock application, being concentrated during the first part of the grazing period, was therefore not really comparable to the one during the previous year, even though the livestock and cattle AUMs were about the same. The precipitation pattern during this year, however, was inadequate and appeared to be the beginning of the range decline.

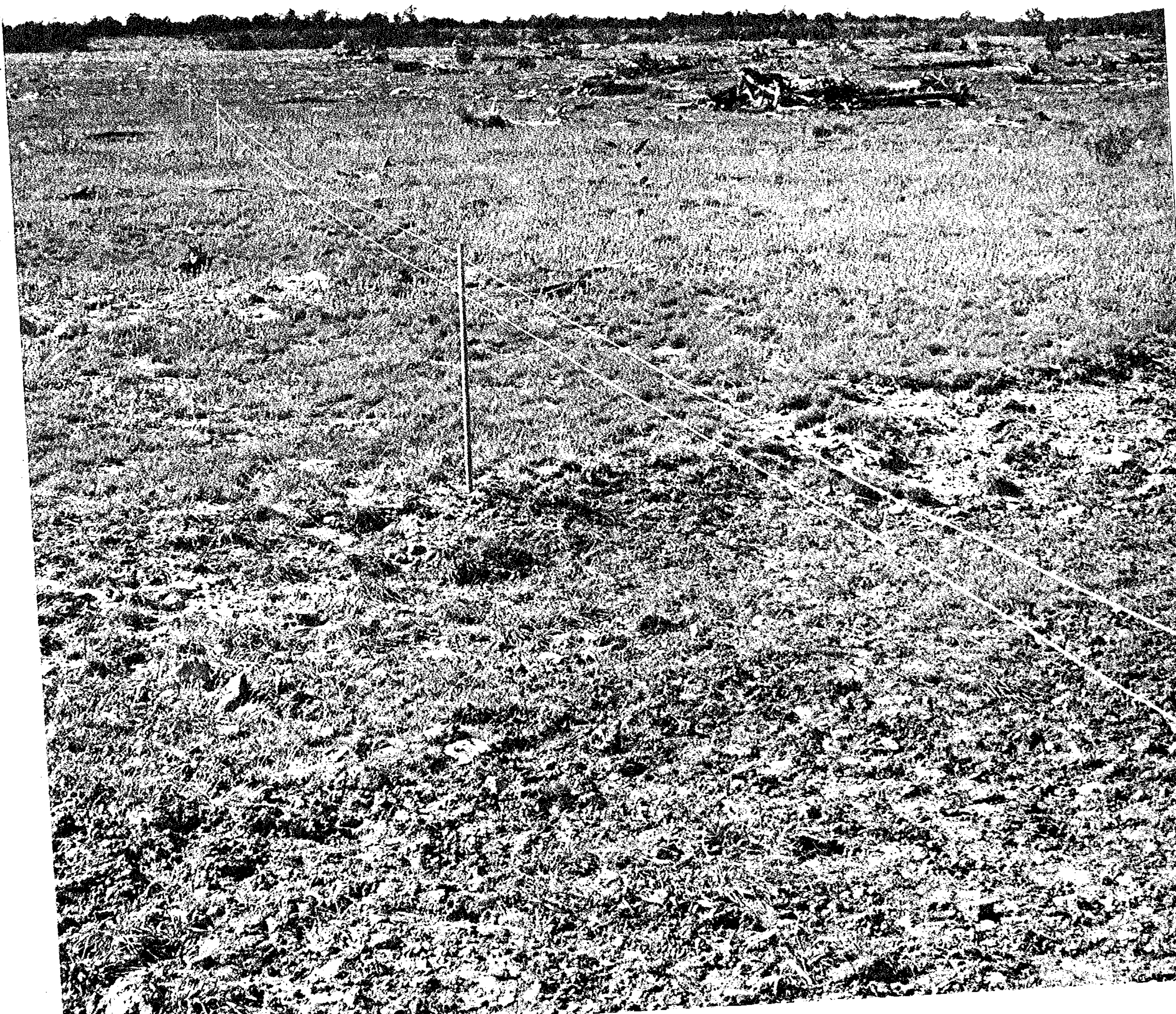
Throughout the 1986-87 winter and the 1987 summer, a total of 4,884 combined AUMs (1,867 livestock and 3,017 elk) were applied to an already stressed range under another inadequate precipitation regimen. Range condition continued to decline and livestock AUMs were reduced again the following year.

Assuming that plants were not weakened during the first year of grazing under HRM, the foregoing seems to indicate that although the cell might have been able to withstand 5,600 AUMs during a good year, 4,900 AUMs were excessive during a dry year. However, the 5,600 figure does represent a substantial increase over what was probably applied during the winter of 1983-84 and summer of 1984, which was about 3,764 AUMs (1,628 cattle and about 2,136 elk, assuming a stable elk population through the 1983-85 period). There was no way to determine whether the plant community sustained any damage during the 1985 season. Therefore, there is a chance that the 5,600 AUM figure was excessive as well. Of interest is the speed with which plant vigor declined, particularly if the range were not damaged during the summer of 1985. USFS reports mention loss of plant vigor during the spring of 1987 and loss of plants at the cell center in 1988.

East Side Versus West Side of Cell. Plant growth was so poor in 1988 that only the early light graze was completed on the west side, and no grazing was conducted on the east side. Following the grazing period, no visually discernible difference existed between the two sides. Because the objective had not been met, the 1988 plan was repeated in 1989, with the west side again the target area. As before, plant growth was so poor that only a light graze was completed between June 8 and July 15. No grazing occurred on the east side. Following this grazing period, a slight difference in average plant height could be seen. In 1990 no stock could be placed on either half of the cell because of poor forage availability and plant condition.

The east half of the cell consistently produced higher pellet accumulation rates than the west half in all years of the study. Therefore the difference between these accumulation rates would indicate any change in elk use, and is given in Appendix 20. The mean of the first three values was significantly different from the mean of the last two ($t = -11.41$, $P \leq 0.1$), but the difference between these two population means (first three years versus last two) was not great. However, the treatments applied during the latter two years were extremely light. To accept the suggestion that grazing of the west side reduced the inequity in elk use levels between the two sides (i.e., increased use levels on the west side to a small degree), it is necessary to acknowledge that early summer grazing in 1988 also produced a measurable effect. These results are far from conclusive. They do, however, suggest that the original theory may still have some validity.

Following page:
Two strand electric fence within a crested wheatgrass monoculture, near the cell center, during September of 1990.



DISCUSSION

From a land management standpoint, this particular HRM application could not be considered very successful. Excessive numbers of livestock in conjunction with adverse climatic conditions initiated a decline in range condition. Livestock numbers eventually were reduced to zero on the cell. During this period, elk populations increased to the point that a depressed range could not recover under the existing climatic conditions, even with substantially reduced livestock densities. None of the wildlife goals could be met. Outbreaks of grasshoppers and black grass beetles occurred during the latter portion of the study. These may have been associated with weakened plant condition. There is nothing within the overall results of this study to suggest that a doubling, or near doubling, of original stocking rates is advisable under HRM on Arizona's rangelands where adverse growing conditions are fairly common.

It is difficult to find fault with the theory behind HRM. Likewise, it is difficult to criticize most of the basic concepts that Savory teaches: establishment of goals, close monitoring of the plant community, close monitoring of animals (both domestic and wild), flexibility in management approach, etc. Within that context however, it is possible to criticize this particular HRM application. There were no established goals at its inception, and the goals in place at the termination of the study were inadequate. In this particular case, we were dealing with a second grazing ungulate, the elk. The major inadequacy of the goals, once they were established, was in their lack of ability to contend with a free-ranging ungulate. A wildlife goal capable of adequately dealing with a second grazing animal would be dependent on all of the following:

1. *A means of monitoring plant condition.* This was done annually on the Quayle cell by the USFS.
2. *A means of monitoring wild grazing ungulate populations.* This monitoring was done twice each year by the Arizona Game and Fish Department at an annual cost of about $10,000. For general management, as opposed to research, one survey per year might be adequate.
3. *A knowledge of how AUMs from wild grazing animals convert to livestock AUMs in any particular situation.* This conversion could be developed for any locality within a 2-year period.
4. *An annual forage allocation for each grazing species.* This management action has political ramifications and is not easily determined. No such prescription was made during this particular study.
5. *A means of controlling the wild ungulate numbers (based on Item 4 above) within at most, a 24-month period and preferably a 12-month period.* In Arizona, hunt permit numbers are approved during the month of May. If a problem were identified during summer or fall, it would be the following May before permit numbers could be modified for the fall and early winter hunts. This schedule would produce a lag time of 12 to 18 months before population levels could actually be reduced.
6. *An understanding of the interaction between the grazing species so that the plant community can be afforded an adequate rest period.* During this particular study the exodus of major wintering concentrations of elk occurred about mid-April but varied by at least three and possibly four weeks across years. Variation in elk movements is something that is difficult, if not impossible, to control and perhaps should not be interfered with at all. The livestock operator would therefore need to adjust his grazing schedules accordingly. This adjustment could amount to a loss of grazing time off the front end of his summer grazing schedule and might affect the termination date as well.

Had all of the above items been functional, the Quayle HRM application might have been more successful. However, Items 3–5 were not established. Subsequently, there was a lack of ability to react to what Items 1 and 2 were indicating. Additionally, Item 2 is worth special consideration. It is obvious that a fairly reliable approach to monitoring game animal populations is required. The Arizona Game and Fish Department assumed this responsibility as part of a limited research activity. They cannot monitor population levels for every HRM application on a general management basis. It is also unlikely that the livestock permittee can devote the necessary effort to this particular activity. This monitoring inability, in itself, suggests a high element of risk if an HRM program is intended to function continuously in conjunction with elk grazing and increased stocking rates. Not falling within this category would be the periodic treatment of portions of pastures through either herding of animals or confinement using temporarily constructed fences.

As late as 1986 Savory was recommending that during times of short food supplies, livestock not be removed from the enclosure. Instead, he advocated rotating them through the individual paddocks at an accelerated rate. This technique was never applied to the Quayle cell. Had it been, the only measurable effects would have been negative. As an alternative, stock were moved to the rest-rotation pastures, which were used as a food reserve.

Arizona's elk herds have been steadily increasing over the past several years. The general population trend on the study area has also been upward. However, it is not known whether these rates of increase were the same. Because the rest-rotation pastures were used to hold excess cattle from the cell, the ability of these pastures to provide control area data has been affected. There was evidence that elk were displaced from the cell to the rest-rotation pastures during the winters of 1987-88, 1988-89, and 1989-90; and also during the summers of 1986, 1987 and 1988. The reason is thought to have been food shortages that were more severe on the cell than on the control. Adding additional confusion to the issue is the suggestion that heavy livestock grazing may have made the local forage supply more attractive to elk. The overall picture probably can be explained in the following manner.

It is unlikely that elk populations in surrounding areas could have increased at a significantly higher rate than those on the study area as a whole. The study area may have actually attracted elk, altering the use patterns of local populations. If so, the rest-rotation pastures eventually became an attractant as well. However, food availability declined within the cell more rapidly than on the rest-rotation pastures, inducing a local shift in elk and levels from the cell to the rest-rotation pastures during both summer and winter. This shift appeared first in the summer use patterns (1986), caused by the direct removal of forage by livestock, and a year later in winter use patterns (1987-88), from a depressed plant community not being able to respond to what little precipitation was received. Negative effects on elk use patterns were seen only when conditions became so severe that livestock grazing itself was being reduced.

This study has documented an adverse effect of HRM on big game populations only under conditions so extreme that they were unacceptable to the livestock operator as well as the elk. The major criticism of additional HRM cell installations within elk habitat lies in the previously discussed area of logistics and administration (i.e., monitoring, control, etc.).

The possibility that recently grazed plants are more attractive to elk than those that have not been recently grazed warrants additional investigation. If grazed areas are more attractive, there are both positive and negative implications. If a second grazing species is present, any area receiving a heavy cattle graze is likely to be grazed again by the wild species before the plant community has had adequate rest. This would mandate a rest from cattle grazing following the grazing by the wild ungulate. The other side of the coin is that a temporary HRM application could be used to attract elk short distances into areas normally receiving light overall use, thereby distributing grazing pressure more evenly over the entire range.

Within Arizona there has been some recent discussion, by both livestock and wildlife interests, on the use of forage allocations for big game and cattle. It is not the intent of this discussion to either recommend or discourage rationing for general use, nor to recommend any particular level of usable forage that should go to either game or livestock. However, the data contained herein provide a somewhat unique opportunity to examine the feasibility of such an approach. One ratio that has been mentioned as appearing to be equitable is a 50:50 allocation of the forage being subjected to competition. The data contained in this report appeared to shed some light on whether or not a 50:50 apportionment was an economically viable option for the livestock industry.

The mean number of elk occupying the cell during the winters of 1984-85 through 1988-89 was 416; the mean number of elk occupying the cell during the summers of 1985-89 was 135 (Appendix 19). A conversion of these figures to AUMs (416 x 7 months = 2,912 winter AUMs and 135 x 5 months = 675 summer AUMs) indicates that 81% of the total annual elk AUMs was applied to the cell during the winter months and 19% was applied during the summer.

If 5,600 total annual AUMs (cow AUMs added to converted elk AUMs to obtain a single expression in terms of cow forage) was a safe level for grazing pressure (page 24), and if a 50:50 allocation of cattle forage is desired; elk would be entitled to 3,752 (67%) of the AUMs based on a 1:1.5 cattle/elk overlap in feeding habits. Cattle would be entitled to 1848 (33%) of the AUMs, all of which would be applied during the summer. Of the 3,752 AUMs allotted to elk, 3,039 (81%) would be applied during the winter and 713 (19%) during the summer. This equates to 434 wintering elk (3039 ÷ 7 months) and 143 summering elk (713 ÷ 5 months).

The livestock AUMs (1,848) represent a 220 AUM increase over the 1984 level (Appendix 1). The elk AUMs do not quite equal those corresponding to the elk densities during the 1986-87 period (Appendix 19). However, the base figure of 5,600 total AUMs is thought to be marginal and perhaps too high.

When the same exercise is conducted using 4,900 total AUMs as an acceptable base figure (page 24) under a 50:50 allocation, 1,617 AUMs would go to cattle and 3,283 would go to elk. This allocation converts to 380 wintering and 125 summering elk. The livestock number was almost identical to that before initiation of HRM, and the elk numbers approximate the transition from the 1985-86 to 1986-87 period. The Bar T Bar stocking rates apparently produced an economically viable operation in 1984; therefore, this observation suggests that a 50:50 allocation based on proper conversion ratios may provide a level of joint use acceptable to both interests.

MANAGEMENT OPTIONS

HRM Cell or Strip Paddocks with All Paddocks in Production Each Year

The initial HRM application on the Quayle cell used this approach. There was no provision for reserve food supplies within the enclosure and little potential for "litter building" (the accumulation of standing forage that could be trampled into the ground at some later date).

HRM Cell or Strip Paddocks with One-Half to Two-Thirds of Paddock in Production Each Year

The remaining one-third to one-half would be used to build litter, meet specific wildlife requirements, and act as an emergency food reserve for cattle. Obviously, reserve food supplies are necessary; therefore, such an approach would seem to be mandatory for the livestock operator whose entire allotment is enclosed within an HRM cell. This type of application was attempted during the last two years of the Quayle HRM study. It was unsuccessful because of an already depressed range condition in conjunction with lack of adequate precipitation. With a healthy range condition and less than excessive numbers of grazing animals, this approach might have been successful.

HRM Cell or Strip Paddocks (as in either option above) Used in Conjunction with a Lightly Stocked Rest-Rotation System That Would also Act as an Emergency Food Reserve for Cattle in the Paddocks

Although not originally intended, this approach was used during the second year of the Quayle Study and every year thereafter. It was unsuccessful because of the presence of excessive numbers of grazing animals. However, if proper stocking had been implemented, it would have provided an adequate means of vegetation control only within the portion of the study area enclosed by the cell. The rest rotation pastures are too large for uniform treatment.

Rest-Rotation Grazing

This type of application has been used for several decades with a limited amount of success. Because relatively large pastures are used, rest-rotation grazing typically produces patterns of overuse in certain areas and nonuse in others.

Rest-Rotation Grazing with Temporary HRM Applications in Specific Areas as the Need Arises

Reduction of plant pedestaling, trampling oxidized feed, etc., could be accomplished using herding techniques or temporary fencing. The existing information suggests that this type of electric fence (two-strand) is more compatible with deer, pronghorn, and elk than conventional barbed wire fences.

However, Savory specifically states that livestock grazing under HRM could be practiced in the absence of any fencing. Within the confines of individual large pastures, periodic spot treatments might be possible. This method, of course, would be contingent upon the cost of temporary fencing or the labor necessary to herd or tend unrestricted animals.

Under this scenario, an HRM application may also be rotated among several rest-rotation pastures across years. Inasmuch as the heavy stocking rates that are used under HRM effectively duplicates some aspects of fire (without soil sterilization) in a grassland community, rotation of HRM application over several years may better emulate natural conditions.

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Following page:
Counting fecal pellet groups within a circular sampling plot.

Appendix 1. History of cattle grazing on the Red Hill management area. Values are expressed as animal unit months (AUM).

YEAR	QUAYLE	RED HILL REST-ROTATION PASTURES	COMBINED TOTAL
1974	2417	1550	3967
1975	2417	1550	3967
1976	2417	1550	3967
1977	2417	1550	3967
1978	1749	1730	3479
1979	1237	1381	2618
1980	1600	1394	2994
1981	1364	1343	2707
1982	1510	1474	2984
1983	1579	1718	3297
1984	1628	1549	3177
Mean	1849	Initiation of HRM	3375
1985	3475	0	3475
1986	3372	1762	5134
1987	1867	1964	3831
1988	1137	862	1999
1989	436	863	1299
1990	0	0	0

Appendix 2. Intended cattle grazing schedule of the Quayle Hill HRM cell and associated pastures between 1985 and 1990.

SEASON	NO. HEAD	DATE ON	DATE OFF	No. DAYS PADDOCK GRAZED		No. DAYS PADDOCK RESTED		DISCUSSION
				Fast Grow	Slow Grow	Fast Grow	Slow Grow	
1964-1984	700	5/1	9/30					
1985[a]	625	4/15	9/15	3	6	42	90	No livestock on rest-rotation pastures 4/15-9/15
1986[b]	864	4/15	9/15	2	4.5	42	90	+ approximately 300 head on rest-rotation pastures for 5 months
1987[b]	680	4/15	9/15	3	6	60	120	+ 300 head on rest-rotation pastures for 5 months
Decision to incorporate cell and rest-rotation pasture stock into a common herd for 1988								
1988[b]	900	5/1	5/31.					Rest rotation pastures
		6/1	7/7					Cell (both halves, light graze)
		7/8	8/16					Rest rotation pastures
		8/17	9/17					Cell (west half only, heavy graze)
1989[b]	325	4/15	Open					Rest rotation pasture obtain one heavy graze on west half of cell as late as possible
1990[b]	300-400	8/1	9/30					Probably rest-rotation pastures and cell but obtain one heavy graze on east half of cell

[a] 16-paddock system

[b] 21-paddock system

Appendix 3. Actual cattle grazing schedule of the Quayle Hill HRM cell and associated pastures between 1985 and 1990.

SEASON	NO. HEAD	DATE ON	DATE OFF	No. DAYS PADDOCK GRAZED		No. DAYS PADDOCK RESTED		DISCUSSION
				Fast Grow	Slow Grow	Fast Grow	Slow Grow	
1985[a]	625	4/15	10/1					
1986[b]	864	4/15	7/2					300 head removed from cell placed in Red Hill Pasture
			8/15					564 head removed from cell placed in Red Hill Pasture
1987	680	4/15	7/1					305 head removed and placed in Maverick Pasture
			7/12					375 head removed and placed in Maverick Pasture. (300 head that had been on the Maverick Pasture since June 1 were remove from the allotment.)
Decision made to incorporate cell and rest-rotation pasture stock into a common herd for 1988								
1988	900	5/1	6/7					Rest rotation-pastures
		6/8	7/15					West half of cell on 7/15 all cattle removed from the allotment
1989	325	5/1	6/30					Rest-rotation pastures
	325	7/1	8/10					West half of cell
	325	8/11	8/31					Rest-rotation pastures
1990	0							

[a] 16-paddock system

[b] 21-paddock system

Appendix 4. Individual observations of elk, mule deer, and pronghorn reactions to electric fences within the cell.

Species	No.	Behavior	Reaction
Pronghorn	1	Disturbed-ran	Over [a]
	7	Disturbed	Parallel
	1	Disturbed	Under
	2	Disturbed	Under
	3	Disturbed	Under
Mule Deer	3	Feeding	Avoid
	3	Disturbed	Over
	4	Feeding	Under
	1	Disturbed	Over
	4	Unknown	Under
	2	Disturbed	Over
Elk	7	Feeding	Over/under
	1	Disturbed	Parallel

[a] Jumped six consecutive fences near hub of cell while running cross country.

Appendix 5. Composition of elk diet during winter.

Species	10/85–4/86	10/88–4/89
GRASSES	%	%
Agropyron spp.	4.3	10.2
Andropogon spp.	0.6	0
Aristida spp.	1.3	0
Bouteloua spp.	8.3	0.8
Bromus tectorum	5.2	0
Bromus rubens	0	4.4
Hilaria jamesii	3.6	0
Hilaria spp.	0	1.3
Muhlenbergia spp.	1.9	0
Schismus barbatus	0.7	0
Unknown spp.	6.3	3.5
TOTAL	**32.2**	**20.2**
FORBS		
Baileya mutiradiata	0.7	0
Boraginaceae spp.	1.5	2.1
Dalea spp.	9.4	1.6
Eriogonum fasiculatum	0	0.9
Erodium cicutarium	0	1.4
Lesquerella gordoni	0.6	1.8
Marubium vulgare	5.1	7.9
Plantago purshii	0	0.5
Psilostrophe sparciflora	2.2	0
Sphaeralcea spp.	5.3	14.2
Vicia exiqua	0	0.5
Unknown spp.	0.8	1.7
TOTAL	**25.6**	**32.6**
SHRUBS		
Argythamnia lanceolata	0	0.9
Artemisia spp.	6.5	0
Atriplex spp.	0	1.2
Brickellia spp.	0.8	0
Ceanothus greggii	3.5	0
Cercocarpus montanus	0	18.4
Cowania mexicana	4.1	9.2
Ephedra spp.	0	1.4
Galium spp.	0	0.5
Gutierrezia spp	0	0.5
Janusia gracilis	0	0.7
Opuntia spp.	0.7	0
TOTAL	**15.6**	**32.8**
TREES		
Juniperus spp.	27.3	13.9
Quercus	0	0.4
TOTAL	**27.3**	**14.3**

Appendix 6. Composition of elk diet during summer.

Species	5/85–9/85	5/89–9/89
GRASSES	%	%
Agropyron spp.	7.2	13.7
Andropogon spp.	0.7	0
Aristida spp.	0	0.7
Bouteloua spp.	20.8	13.5
Bromus tectorum	7.4	0
Bromus rubens	0	2.1
Hilaria jamesii	5.2	0
Muhlenbergia spp.	0.6	0
Poa spp.	0	0.3
Unknown spp.	3.9	2.0
TOTAL	**45.8**	**32.3**
FORBS		
Astragalus spp.	4.1	0
Boraginaceae spp.	0.8	0
Dalea spp.	15.2	2.4
Eriogonum fasiculatum	0	1.2
Eriogonum spp.	0	0.4
Erodium cicutarium	0.8	1.7
Gilia aggregata	1.4	0
Lesquerella gordoni	2.0	0.7
Lupinus spp.	1.2	0.4
Marubium vulgare	0.6	5.0
Melilotus spp.	0.7	0
Notholaena parryi	0.6	0
Plantago purshii	0	0.4
Polygala alba	0	0.4
Sphaeralcea spp.	4.9	8.4
Unknown Forbs	2.0	0.7
TOTAL	**34.3**	**21.7**
SHRUBS		
Artemesia spp.	1.8	0.4
Atriplex spp.	0	1.1
Berberis fremontii	0.6	0
Berberis repens	0	0.6
Cercocarpus montanus	0	15.1
Cowania mexicana	0.7	11.3
Ephedra spp.	0	0.4
Eurotia lanata	0	0.4
Krameria spp.	0	0.7
Opuntia spp.	2.6	0
Viguiera deltoidea	0	0.4
TOTAL	**5.7**	**30.4**
TREES		
Juniperus spp.	4.0	9.7
Quercus spp.	9.3	5.7
TOTAL	**13.3**	**15.4**

Appendix 7. Composition of cattle diet during summer.

Species	5/85–9/85	5/89–9/89
GRASSES	**%**	**%**
Agropyron spp.	4.6	7.8
Andropogon spp.	0	0.7
Aristida spp.	0.9	2.3
Bouteloua spp.	74.4	58.4
Bromus rubens	0.3	0
Hilaria jamesii	4.9	0
Hilaria spp.	0	3.2
Muhlenbergia spp.	0.6	0.5
Oryzopsis hymenoides	0	0.6
Phleum pratense	0	0.3
Schismus barbatus	0	0.6
Sitanion hystrix	0	0.6
Sporobolus spp.	0.3	1.6
Unknown spp.	2.1	4.5
TOTAL	**88.1**	**81.1**
FORBS		
Boraginaceae spp.	0.6	0.3
Dalea spp.	3.4	0
Eriogonum fasiculatum	0	0.3
Erodium cicutarium	0	0.3
Lesquerella gordoni	0.6	1.3
Marubium vulgare	0	3.2
Plantago purshii	0.6	0
Psilostrophe cooperi	0	1.4
Sphaeralcea spp.	1.8	6.2
Unknown spp.	0.5	1.1
TOTAL	**7.5**	**14.1**
SHRUBS		
Ambrosia dumosa	0	0.3
Artemesia spp.	1.4	0
Atriplex spp.	0	0.7
Berberis freemontii	0.6	0
Cercocarpus montanus	0	0.5
Eurotia lanata	0	0.6
Encelia frutsescens	0.7	0
Ephedra spp.	0.4	0
Opuntia spp.	0.3	0.6
Salazaria mexicana	0	0.3
Yucca spp.	0	2.2
TOTAL	**3.4**	**5.2**
TREES		
Juniperus	0.6	0
Quercus	0.6	0
TOTAL	**1.2**	**0**

Appendix 8. Selection of vegetation and topography by elk.

ITEM	WINTER					SUMMER				
	p[a]	% Available	% Used	Difference p≤ 0.1[b]	Jacobs' D	p[a]	% Available	% Used	Difference p≤ 0.1[b]	Jacobs' D
Topography (gulch, swale, stony flat, long gentle slope, narrow ridgetop)	0.2694					0.2854				
Aspect	0.0000					0.0206				
North		0.340	0.341	=	0.002		0.340	0.332	=	–0.018
East		0.397	0.429	=	0.064		0.397	0.419	=	0.046
South		0.114	0.091	=	–0.131		0.114	0.114	=	0.001
West		0.149	0.140	=	–0.036		0.149	0.135	=	0.167
Slope (0-3°, 3-6°) (6-12°, >12°)	0.2328					0.1242				
P/J Treatment	0.0069					0.9361				
Not Chained		0.182	0.164	=	–0.283					
Chained		0.818	0.836	=	0.063					
P/J Old Growth	0.0068					0.4157				
Not Present										
	0.858	0.875	=		0.073					
	0.142	0.125	=		–0.074					
Cliffrose	0.0000					0.0000				
Not Present		0.401	0.350	–	–0.109		0.402	0.312	–	–0.180
Present		0.599	0.650	+	0.109		0.598	0.688	+	0.194
Shrub Cover	0.0005					0.0030				
0%		0.101	0.098	=	–0.017		0.101	0.087	=	–0.082
<5%		0.515	0.486	=	–0.058		0.515	0.474	=	–0.082
5-25%		0.326	0.346	=	0.045		0.325	0.354	=	0.065
25-75%		0.057	0.067	=	0.086		0.057	0.080	=	0.179
>75%		0.002	0.004	=	0.339		0.002	0.005	=	0.429
Max Shrub Height	0.0179					0.0003				
0 ft		0.100	0.097	=	–0.017		0.101	0.085	=	–0.095
1 ft		0.015	0.016	=	0.033		0.015	0.010	=	–0.202
2 ft		0.134	0.127	=	–0.031		0.134	0.112	=	–0.102
3 ft		0.109	0.105	=	–0.019		0.109	0.095	=	–0.077
4 ft		0.130	0.126	=	–0.018		0.130	0.120	=	0.034
5 ft		0.129	0.128	=	–0.004		0.129	0.147	=	0.340
6 ft		0.185	0.206	=	0.067		0.185	0.240	=	0.164
7 ft		0.093	0.093	=	0.000		0.093	0.104	=	0.062
8 ft		0.077	0.075	=	0.014		0.077	0.065	=	–0.090
9 ft		0.011	0.012	=	0.043		0.011	0.010	=	–0.048
10 ft		0.016	0.016	=	0.000		0.016	0.012	=	–0.143

Appendix 8. (continued) Selection of vegetation and topography by elk.

ITEM	WINTER					SUMMER				
	p[a]	% Available	% Used	Difference $p \leq 0.1$[b]	Jacobs' D	p[a]	% Available	% Used	Difference $p \leq 0.1$[b]	Jacobs' D
Dominant Shrub Species	0.0000					0.0000				
Cliffrose/ Mahogany		0.487	0.547	+	0.120		0.486	0.569	+	0.157
No Shrubs		0.256	0.255	=	0.003		0.257	0.225	=	–0.087
Other Shrubs		0.155	0.125	–	0.119		0.154	0.123	=	–0.125
P/J		0.103	0.072	–	–0.194		0.103	0.082	=	–0.113
Forb/ Half Shrub Cover	0.1421					0.2081				
0-<5%										
5-25%										
25-75%										
>75%										
Dominant Forb/ Half Shrub Species	0.8340					0.7944				
Grass Cover	0.0001					0.3993				
0%										
<59%		0.009	0.007	=	–0.125					
5-25%		0.166	0.139	=	–0.104					
25-75%		0.348	0.348	=	0.000					
>75%		0.459	0.489	=	0.060					
		0.018	0.017	=	–0.029					
Dominant Grass Species	0.0000					0.0181				
Cool Season		0.229	0.263	+	0.091		0.228	0.269	=	0.109
No Grass		0.007	0.006	=	–0.094		0.007	0.008	=	0.067
Warm Season		0.764	0.731	–	–0.087		0.764	0.723	=	–0.119
Surface Stone	0.0000					0.2241				
0%		0.087	0.094	=	0.042					
<5%		0.232	0.240	=	0.022					
5-25%		0.285	0.294	=	0.022					
25-75%		0.350	0.330	=	–0.045					
>75%		0.046	0.043	=	–0.030					

[a] Significance level of the χ^2 statistic
[b] + Significant Selection
– Significant avoidance
= No significant difference

Appendix 9. Selection of vegetation and topography by cattle.

ITEM	SUMMER				
	P[a]	% Available	% Used	Difference[b] p ≤ 0.1	Jacobs' D
Topography	0.0000				
Gulch		0.073	0.047	–	–0.230
Swale		0.092	0.115	=	0.124
Stony Flat		0.040	0.048	=	0.099
Alluvial Rabbit Brush		0.029	0.036	=	0.200
Long Gentle Slope		0.759	0.749	=	–0.027
Narrow Ridge Top		0.007	0.005	=	–0.130
Aspect	0.0628				
Slope	0.0000				
0-3°		0.365	0.435	+	0.139
3-6°		0.400	0.419	=	0.039
6-12°		0.168	0.117	–	–0.209
>12°		0.067	0.030	–	–0.399
P/J Treatment	0.0000				
Not Chained		0.182	0.095	–	–0.987
Chained		0.818	0.905	+	0.360
P/J Old Growth	0.0000				
Not Present		0.857	0.041	+	0.433
Present		0.143	0.059	–	–0.454
Cliffrose	0.0000				
Not Present		0.401	0.448	+	0.096
Present		0.599	0.552	–	–0.582
Shrub Cover	0.2414				
Maximum Shrub Height	0.0004				
0 ft		0.101	0.113	=	0.059
1 ft		0.015	0.022	=	0.194
2 ft		0.134	0.162	=	0.111
3 ft		0.109	0.103	=	–0.032
4 ft		0.130	0.113	=	–0.079
5 ft		0.129	0.113	=	0.075
6 ft		0.185	0.175	=	–0.034
7 ft		0.093	0.090	=	–0.840
8 ft		0.077	0.085	=	0.054
9 ft		0.011	0.010	=	–0.057
10 ft		0.016	0.014	=	–0.068
Dominant Shrub Species	0.0000				
Cliffrose/Mahogany		0.485	0.443	=	–0.084
No Shrubs		0.256	0.308	+	0.128
Other Shrubs		0.154	0.140	=	–0.163
P/J		0.103	0.109	=	0.032
Forb/Half Shrub Cover	0.1714				

Appendix 9. (continued) Selection of vegetation and topography by cattle.

ITEM	SUMMER				
	p[a]	% Available	% Used	Difference[b] $p \leq 0.1$	Jacobs' D
Grass Cover	0.0000				
0%		0.009	0.011	=	0.100
<5%		0.167	0.083	–	–0.356
5-25%		0.348	0.352	=	0.009
25-75%		0.459	0.527	+	0.135
>75%		0.018	0.027	=	0.205
Dominant Grass Species	0.3251				
Surface Stone	0.0000				
0%		0.087	0.119	+	0.173
<5%		0.232	0.289	+	0.145
5-25%		0.285	0.300	=	0.036
25-75%		0.350	0.270	–	–0.186
>75%		0.046	0.022	–	–0.364

[a]Significance level of the χ^2 statistic
[b]+Significant Selection
– Avoidance
= No Significant Difference

Appendix 10. Recorded amounts of precipitation falling on the Quayle Hill HRM cell (cm).

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
1985			Adequate[a]				Adequate[a]		
1986	0.00	0.00	trace	0.00	1.32	0.58	4.98	6.32	?
1987			0.28				6.60		
1988	?	?	0.00	0.76	0.00	3.30	1.40	8.13	?
1989	?	?	0.00	0.00	0.10	0.00	[b]	?	?

[a] General assessment (Ken Vensel, pers. commun.) rain gauge broken
[b] Storm of unkown magnitude on about July 20

Appendix 11. Forage production and use estimates of the Quayle Hill HRM cell measured during October of each year (Vensel and Mundell 1990).

YEAR	kg PRODUCED	kg USED	% USED
1985	2,110,021	583,567	28
1986	1,115,497	381,952	34
1987	995,545	319,422	32
1988	1,023,068	276,691	27
1989	879,720	305,100	35

Appendix 12. Forage production and utilization estimates rest-rotation pastures (measured October of each year).

YEAR	PASTURE	kg PRODUCED	kg USED	% USED
1986	Red Hill	397,937	149,191	37
1986	Maverick	505,120	162,386	32
1986	Diannes	278,029	105,478	38
1987	Maverick	396,712	151,103	38
1987	Diannes	210,898	83,729	40
1988	Red Hill	451,256	142,403	32
1988	Maverick	390,951	65,252	17
1988	Diannes	240,495	45,434	19
1989	Red Hill	371,265	169,235	46
1989	Maverick	338,584	94,098	28
1989	Diannes	256,960	101,484	39

Appendix 13. Bar T Bar Ranch Company, cattle performance summary, 1984–89, Quayle–Red Hill pastures.

	1989	1988	1987	1986	1985	1984
No. of Head	144 heifers 179 spays 8 bulls	463 heifers	676 steers	618 steers	620 steers	610 steers
ON Weight Net (kg)	228 heifers 181 spays	205 heifers 171 spays	218 steers	215 steers 172 heifers	224 steers	246 steers
OFF Weight Net (kg)	329 heifers 281 spays	263 heifers 223 spays	359 steers	342 steers 298 heifers	380 steers	366 steers
Average Daily Gain (kg)	0.67 heifers (151 days) 0.66 spays (153 days)	0.77 heifers 0.68 spays	0.93	0.76	0.94	0.80
Total Gain (kg/Head)	101 heifers 100 spays	59 heifers 52 spays	141 steers	127 steers 126 heifers	156 steers	120 steers
Total kg Beef Produced	8,362 Quayle (39 days) 24,250 Red Hill **32,612 Total**	24,239 Quayle 24,240 Red Hill **48,479 Total**	51,605 Quayle 42,910 Red Hill **94,575 Total**	75,871 Quayle 32,870 Red Hill **108,741 Total**	96,461 Quayle	73,047 161,040 Total
Total kg/ha	2.41 Quayle (3470 ha) 5.27 Red Hill (4600 ha) 4.04 Overall	6.98 Quayle 4.99 Red Hill 5.83 Overall	14.87 Quayle 8.85 Red Hill 11.35 Overall	22.08 Quayle 6.77 Red Hill 13.44 Overall	28 Quayle	9 Overall
Total Days Grazed	153/151	76	152	167	165	150
HRM	Y	Y	Y	Y	Y	Y

Appendix 14. Estimated average percent use, by weight for individual paddocks each time livestock was moved.

YEAR	PORTION OF PADDOCK			PADDOCK AVERAGE
	Inner Third	Middle Third	Outer Third	
1985	45-80%	21-45%	0-20%	30%
1986	45-80%	45-80%	45-80%	60-70%
1987	45-80%	21-45%	0-20%	50%

Appendix 15. Monthly diaminopimelic acid (DAPA) content of elk fecal material collected from the Quayle Hill cell. Values are expressed as milligrams per gram.

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MEAN
1984-85	0.769	—	—	0.426	0.466	0.468	0.651	0.55
1985-86	0.460	0.546	0.510	—	—	—	0.841	0.59
1986-87	0.771	—	0.426	—	0.439	0.316	0.528	0.48
1987-88	0.439	0.505	0.414	0.438	0.456	0.465	—	0.45
1988-89	—	—	0.450	0.434	—	0.482	0.599	0.49

Appendix 16. Game Management Unit 5A elk hunting permit numbers.

YEAR	SEX	ARCHERY	MUZZLE LOADER	CENTER FIRE	TOTAL BY SEX	TOTAL BOTH SEXES
1984	Any	175	0	125	300	950
	Bull	400	0	250	650	
1985	Antlerless	180	0	130	310	1010
	Bull	435	0	265	700	
1986	Antlerless	180	0	130	310	1010
	Bull	435	0	265	700	
1987	Antlerless	200	0	150	350	1065
	Bull	450	0	265	715	
1988	Antlerless	200	0	150	350	1065
	Bull	450	0	265	715	
1989	Antlerless	100	125	300	525	1125
	Bull	200	50	350	600	

Appendix 17. Annual winter deer and pronghorn (combined) fecal deposition rates.

PELLET GROUPS/0.4 ha/DAY		
YEAR	CELL	REST-ROTATION PASTURE
1984-85	0.0848	——
1985-86	0.0941	0.0456
1986-87	0.0684	0.0365
1987-88	0.1157	0.1032
1988-89	0.0765	0.0219
1989-90	0.0692	0.0213

Appendix 18. Annual summer deer and pronghorn (combined) fecal deposition rates.

PELLET GROUPS/0.04 ha/DAY		
YEAR	CELL	REST ROTATION PASTURE
1985	0.0589	0.0950
1986	0.0499	0.0219
1987	0.0781	-0-
1988	0.0201	0.0318
1989	0.0631	0.0120

Appendix 19. Estimated seasonal numbers of elk occurring on the study area.

CELL				CELL AND REST ROTATION PASTURES			
WINTER		SUMMER		WINTER		SUMMER	
YEAR	NO. ELK	YEAR	NO. ELK	YEAR	NO. ELK	YEAR	NO. ELK
1984-85	315	1985	128				
1985-86	356	1986	67	1985-86	459	1986	245
1986-87	442	1987	215	1986-87	592	1987	559
1987-88	497	1988	122	1987-88	891	1988	311
1988-89	471	1989	144	1988-89	904	1989	211
1989-90	364	1990	160[a]	1989-90	700	1990	360[a]

[a] No data. Average of last 3 years used.

Appendix 20. Annual difference between elk fecal pellet deposition rates of the east and west halves of the Quayle Hill cell (east minus west).

WINTER	Pellet Groups/0.4 ha/DAY
1985-86	0.1058
1986-87	0.2063
1987-88	0.1729
1988-89	0.0300
1989-90	0.0047

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