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Rangeland Livestock Production: Developing the Concept of Sustainability on the Santa Rita Experimental Range

Abstract: The Santa Rita Experimental Range (SRER) was established in 1903 at the behest of concerned stockmen and researchers as the first facility in the United States set aside to study range livestock production. At the time, severe overgrazing of the public domain had seriously reduced carrying capacities of Southwestern rangelands. Researchers on the SRER developed and demonstrated the concepts that became the foundation for the art and science of range management. These included improved livestock husbandry methods and an initial understanding of how grazing behavior influenced patterns of vegetation response. The emphasis for range livestock production research, however, quickly focused on stocking levels and adjusting grazing and rest periods in order to maintain or improve the abundance and production of forage grasses. Subsequent research developed and demonstrated methods to achieve sustainable range livestock production based on limited herd flexibility and controlled forage utilization levels determined by stocking and monitoring histories. These concepts, conceived and tested on the SRER, contributed greatly to the foundation of modern range management.

Acknowledgments: Some of the following data sets were accessed via the Santa Rita Experimental Range Digital Database. Funding for the digitization of these data was provided by the USDA Forest Service, Rocky Mountain Research Station, and the University of Arizona. Additionally, much material from the Santa Rita Experimental Range archives was reviewed in the preparation of this manuscript. The effort of those involved in the archiving process is greatly appreciated. The author gratefully acknowledges Don Dwyer, Larry Howery, Barbara Hutchinson, and Phil Ogden for their thoughtful reviews.

Introduction

The Santa Rita Experimental Range (SRER) was established in 1903 when it was fenced out of the public domain. Establishment of the SRER was a direct result of pressure from the livestock industry and concern by university and agency researchers of the time that range productivity, in terms of livestock carrying capacity, had declined considerably. In the preface to Griffiths (1901), agrostologist F. Lawson-Scribner wrote that the “free-range system has led to the ruthless destruction of the native grasses” and stressed the “urgent needs of the stockmen for better range conditions.” Griffiths (1901) recognized that “ranchers and those interested in stock growing are beginning to realize more and more the importance of placing the range management in the hands of some one having authority and an interest in its preservation.” This authority, whether at the State or Federal level, also required scientifically accepted criteria for range management, criteria that needed to be developed and tested. Thus began the application of the art and science of range management to Southwestern rangelands.

The SRER was specifically established to conduct “ecological research related principally to the range livestock industry” (Martin and Reynolds 1973). This research program was developed to provide the science on which to base modern range livestock production. Principle audiences for the research were ranchers and Federal agency field personnel (Roach 1950), particularly the USDA Forest Service, which was assigned to conduct range research in 1915. For nearly eight decades the Forest Service directed the research program on the SRER. Livestock grazing has continued on the SRER, but by the early

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In: McClaran, Mitchel P.; Ffolliott, Peter F.; Edminster, Carleton B. tech. coords. Santa Rita Experimental Range: 100 years (1903 to 2003) of accomplishments and contributions; conference proceedings; 2003 October 30–November 1; Tucson, AZ. Proc. RMRS-P-30. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

1970s, research emphasis had shifted to studies on the "impacts of grazing on the ecosystem" and more basic ecological aspects of "semidesert ecosystems" (Martin and Reynolds 1973). A broader audience of "working ecologists" and the "urban public" had also emerged.

The emphasis for research may have been livestock production, but from the beginning, the SRER was a range manager's place and the range vegetation was their primary focus. Range livestock grazing research on the SRER developed and promoted the concept of conservative use and sustainability. In 1975, Martin wrote that "Research and experience indicate that ranges can be grazed at any time of year without serious detriment if the intensity of grazing is not too severe, and if periods of grazing alternate with suitable periods of rest" (Martin 1975a). The objectives of this paper are to examine the body of knowledge generated on the SRER related to range livestock production systems that led to these beliefs; discuss the concepts, methods, and tools developed to apply them; and present stocking histories that indicate the sustainability of conservative stocking. I provide this manuscript as a tribute to all of the early researchers, but especially to S. Clark Martin who spent much of his long and distinguished career on the Santa Rita.

Grazing History

Early records well document the overstocking and deterioration of southern Arizona rangelands. Livestock were first introduced into southern Arizona in the late 1600s by Father Kino and early Spanish explorers (Allen 1989; Sheridan 1995), but Spanish ranching did not begin in earnest until the beginning of the next century (Sheridan 1995). It is easy to assume that ranges, where adequate water was available, were fully stocked by Spanish and Mexican ranches in the early 1800s. These early ranches were abandoned around 1840, but wild cattle in unknown numbers remained on the ranges. Anglo ranchers began their influx soon after the Civil War (Sheridan 1995). Range cattle, as well as sheep and goat, numbers increased after about 1870 and skyrocketed by the mid-1880s. It was commonly reported that the number of cattle in the Arizona Territory was about 5,000 in 1870, 230,000 in 1880, 650,000 in 1885, and over one million in 1890. Dieoffs followed due to the combined effects of overstocking and drought (Griffiths 1901). Severe summer drought in 1891 and 1892 resulted in cattle losses of up to 75 percent by late spring of 1893 (Martin 1975a). Nonetheless, stocking on Arizona ranges continued to exceed carrying capacities well into the 1900s. Stockmen and government agency researchers alike attributed overstocking to open range policy. It was a direct result of these conditions and the importance of finding ways to stabilize the range livestock industry that led to the establishment of the Santa Rita Experimental Range. The SRER was fenced in 1903, destocked, and allowed ungrazed "recovery" until 1914 (Martin and Reynolds 1973). After 1915 most of the area was continuously grazed until 1957 when various schedules of rest were implemented in study pastures.

Sustainable Grazing

At the beginning of Anglo settlement it was thought that the primary economic resources of the Arizona Territory would come from minerals, but it was soon determined that rangeland vegetation, especially the *Bouteloua* (grama) grasses in the south, provided a vast forage resource for livestock production. For the range livestock industry to become a stable, long-term, economic base, however, the art and science of range management had to be developed and applied. This became a reality with the establishment of the SRER.

The theory and philosophy of the sustainability of range livestock production was pioneered on the SRER. The concept was variously referred to from the earliest writings as "the amount of stock that these lands will carry profitably year after year" (Griffiths 1904), "keeping utilization in harmony with forage supply" (Roach 1950), "sustained use without deterioration of rangelands" (Reynolds 1954), and providing "relatively stable livestock production without seriously impairing other important resource values" (Martin and Reynolds 1973). Overgrazing was recognized early as the primary deterrent to sustainable range livestock production and characterized by observations such as "the tops are continually eaten to the ground" causing the roots to "gradually become extinct" (Griffiths 1901). The sustained production of perennial grass forage for range livestock production "requires grazing the desirable plants to the proper degree at appropriate times and the optimum distribution of livestock" (Reynolds and Martin 1968). These concepts were developed and applied on the SRER.

Range livestock production was a primary livelihood in Arizona when the SRER was established. While decreasing in economic importance over the years, grazing has continued on Southwestern semidesert ranges. Martin (1975b) stated that these rangelands produced enough beef for nearly 3 million people using only a third of the energy required of other food production systems. The harvesting of range forage, produced almost totally from solar energy, remains the most basic way to convert sunshine to food. Rangeland livestock production remains the most widespread use of Arizona rangelands (Ruyle and others 2000). Range management practices developed on the SRER have allowed ranges to improve and maintain productivity over time, and have led to the continued production of range livestock.

The following describes the primary literature and basic findings that supported the development and application of sustainable range livestock production practices.

Range Management and Livestock Production

Most of the researchers connected with the SRER equated range management with range livestock production. That is, their range management practices were focused on increasing forage for livestock on semidesert ranges. The categories below represent the primary literature related to range livestock production on the SRER. Much of the literature has been reviewed in earlier publications, albeit with a different time reference.

By far the majority of research on the SRER did not focus on livestock per se, although animal weights, especially of weaned calves, were often recorded. Instead, the emphasis was on the range vegetation for the purpose of managing grazing to improve and/or maintain the amount and distribution of perennial grasses.

Effects of Grazing on Plant Communities

General impacts of open range grazing and unrestricted livestock numbers were well documented at the turn of the century. These included loss of forage productivity and increases in plant species less palatable to livestock, bare ground, and soil erosion. The fact that semidesert ranges were vegetated by bunchgrasses rather than sod-forming grasses increased the susceptibility of the soil surface to “injury by trampling” (Griffiths 1901), which seemed to surprise early observers (Toumey 1891). While overgrazing was known and described, the ecological processes involved were only beginning to be studied in an experimental fashion when the SRER was established.

Grazing can influence all vegetation of the range, primarily through selective herbivory on plant species over time and space. Plants vary greatly in palatability to livestock, and the preferred species tend to get grazed heavily, especially when animals are allowed to graze yearlong (Reynolds and Martin 1968). Selective grazing can change the composition of the plant community and reduce the productivity of the primary forage species. These now well-known processes were demonstrated in descriptive studies and then experimentally in small plot and pasture studies on the SRER.

In addition to the many early comparisons of ungrazed versus heavy, continuous, yearlong grazing, vegetation differences associated with distance from water were demonstrated on a pasture with a single permanent water source, and grazed yearlong for a 38-year period (1930 to 1968) (Martin 1972). Heavy, moderate, and light use zones, moving away from water, were associated with about 70-, 50-, and 25-percent utilization, respectively. Differences in grazing use zones manifested species composition shifts among the palatable perennial grasses. Heavy use (usually over 70 percent by weight) reduced the percent composition of *Bouteloua eriopoda* Torr. (black grama), *Tridens muticus* (Torr.) Nash (slim tridens), and *Muhlenbergia porteri* Scribn. Ex Beal (bush muhly), and favored *Aristida californica* Thurber var. *glabrata* Vasey (Santa Rita threeawn) and *Bouteloua rothrockii* Vasey (Rothrock grama). More moderate stocking was shown to improve composition of the aforementioned midgrasses in later studies. Recovery potential of overgrazed rangeland, although limited by increases in mesquite, had been demonstrated early on the SRER and, along with determining proper stocking levels, were research themes for many years (Wooton 1916).

Early range researchers commonly used various clipping intensities on range grasses to simulate grazing, although the limitations of extrapolating data from clipped plots to pasture level grazing processes were recognized (Culley and others 1933). Clipping studies on the SRER compared intensity and frequency of defoliation on several perennial grasses. Findings demonstrated aboveground production was reduced by 50 percent on plants clipped weekly during the growing season to 1-inch stubble compared to plants clipped to that level only once at the end of the growing season (Reynolds and Martin 1968).

Research also demonstrated plant community differences by comparing protected areas with adjacent areas grazed continuously (Griffiths 1910). Species most abundant under continuous yearlong grazing were *Hilaria belangeri* (Steud.) Nash (curley mesquite), Rothrock grama, and *Bouteloua filiformis* (Fourn.) (slender grama), and species favored by protection were *Digitaria californica* (Benth.) Henr. (Arizona cottontop), bush muhly, black grama, *Bouteloua curtipendula* (Michx.) Torr. (sideoats grama), *Aristida* species (threeawns), *Eragrostis intermedia* Hitchc. (plains lovegrass), and *Leptochloa dubia* (H.B.K.) Nees (green sprangletop) (Canfield 1948; Reynolds and Martin 1968). Grazing pressure resulted in about 50-percent utilization on the group of species most abundant where grazing was continuous and was “much heavier” on the grasses that responded most to protection from grazing. Other studies failed to demonstrate such benefits to the more palatable midgrasses with protection from grazing, especially under moderate use levels (approximately 40 to 60 percent averaged over species and years) (Canfield 1948) or when shrub cover (primarily *Prosopis juliflora* var. *velutina* (Woot.) Sarg. (mesquite)) was dominant (Caraher 1970; Glendening 1952).

General Range Animal Husbandry

Many changes were seen in the principles and methods of raising cattle in the Southwest during the first several decades after establishment of the SRER. The Superintendent of the SRER from 1921 to 1950, Matt Culley, recognized that modern business and range management methods were necessary for ranching success. Most ranches were “run as breeding operations” with the chief source of income being calves sold in the fall or as yearlings the following year (Culley 1946a). Therefore, the percentage of calves produced was of extreme importance. Research on the SRER suggested several factors that increased herd production and earnings (Culley 1937a, 1946a,b,c, 1947, 1948). These included “stocking the range on the basis of sustained yield,” reducing pasture size, increasing watering places, regulating the breeding season, and reducing death loss. Improving general management practices with mechanical livestock handling aids was also suggested. Marketing strategies were also evaluated, but as Parker (1943) wrote, “the condition of the range should always be considered first” in deciding when to sell the animals. Such a strategy required a flexible approach to fall weaning and culling. In good years calves could be held over, and in drought conditions even breeding cows might need to be sold.

Although influenced by grazing pressure and the impact of droughts on forage production, calf crop and calf weights increased remarkably on the SRER after the 1920s, due to general improvements in animal genetics and handling methods (Reynolds 1954) as well as reductions in grazing pressure (Martin 1943). For example, in the 1943 *Hereford Journal*, Martin reported increased average annual calf production per cow was 192 pounds to 368 pounds, depending on stocking rates that ranged from 30 to 70 acres per cow. The average cow produced 44 pounds more in calf weight with each additional 10 acres of range she was allowed to graze. Improvements in the kind of cattle, in terms of breeding, nutrition, and culling practices, also contributed to these gains. Hereford cattle predominated on the SRER for much of its history, but after the mid-1960s they were gradually being replaced with crossbred herds (Culley 1946b; Martin 1975a).

Grazing Behavior

Grazing Habits—An important aspect of effective range management is the study of grazing behavior of cattle on the range (Culley 1937b, 1938a). Culley was interested in the relative preference by cattle for different forage plants as well as the general grazing behavior of cattle. He determined that some forage species were grazed "indiscriminately" year round while others were primarily selected seasonally. Culley also described cattle grazing patterns and activity budgets on a seasonal basis. He reported summer and winter grazing periods of 7 and 8 hours a day, and spring grazing averaged 9 hours daily. Fall and early summer grazing was confined to grasses along washes. Mesquite and *Acacia greggii* A. Gray (catclaw) were used during the winter and late spring, and other shrubs were browsed throughout most of the year. Zemo and Klemmedson (1970) further quantified activity budgets using fistulated steers and concluded that their experimental animals responded in a similar fashion to intact animals as reported in other studies. However, they did record a higher amount of night grazing than most other observations.

Gamougoun (1987) related cattle activity budgets to characteristics of available forage. He found that cattle grazed longer during the summer than in winter and walked more in heavily grazed pastures than in more moderately grazed areas. Gomes (1983) compared behavioral activities of Hereford and Barzona cows and recorded almost identical daily activities.

Ruyle and Rice (1996) described more recent and detailed cattle feeding behavior studies conducted in pastures on the SRER that primarily supported *Eragrostis lehmanniana* Nees (Lehmann lovegrass) stands. Cattle grazing utilization patterns on these pastures resulted in heavily grazed patches interspersed throughout ungrazed or lightly grazed areas (Ruyle and others 1988). Cattle spent approximately 80 percent of their grazing time feeding in previously grazed patches and only slightly altered this ratio with increasing stocking rates (Abu-Zanat 1986; Nascimento 1988; Ruyle and Rice 1996). Cow biting rates were higher and bite sizes usually smaller when feeding in heavily grazed patches versus lightly grazed areas (Ruyle and others 1987; Ruyle and Rice 1996). Higher nutrient densities and a reduced presence of residual stems in grazed patches were thought to be the primary factors influencing cattle grazing strategies in pastures dominated by Lehmann lovegrass.

Diet Selection—Plant species vary in palatability seasonally and among life forms, and cattle prefer new green forage, shifting their diets in several ways to accommodate this preference (Lister 1938a,b, 1939). Santa Rita researchers observed these differences empirically and experimentally and attempted to use them to control grazing distribution and use on the various classes of forage (Canfield 1942a; Lister and Canfield 1934; Reynolds and Martin 1968). Most perennial forage grasses were grazed throughout the year. Arizona cottontop was more heavily grazed in the summer, and black grama and bush muhly were grazed most heavily in the winter. Cable and Bohning (1959) were first to demonstrate that the exotic Lehmann lovegrass, introduced from South Africa, was primarily grazed during the spring when it occurred in mixed stands with native perennial grasses.

More exact methods to quantify range cattle diet selection were employed beginning in the early 1960s on the SRER. However, these researchers usually estimated only the crude protein content of diets (Shumway and others 1963). A method to estimate botanical composition of diets from fistulated animals was tested and diet selection results reported in later studies (Galt and others 1968, 1969, 1982). These studies verified earlier results demonstrating that certain species were preferred throughout the year while others were selected seasonally. Summer preference for Arizona cottontop and *Setaria macrostachya* H.B.K. (plains bristlegrass), winter and spring consumption of black grama and Lehmann lovegrass, summer use of slender grama, spring use of Rothrock grama, and winter and summer selection of mesquite and *Calliandra eriophylla* Benth. (false mesquite) were again demonstrated.

Nutrition

Early studies indicated that the primary forage grasses on the SRER did not provide adequate crude protein or phosphorous during the driest times of the year, usually December to February and May and June (Hubber and Cable 1961). These findings were substantiated by later work. Using fistulated animals, researchers demonstrated that steers selected diets much higher in crude protein than hand-clipped samples, although the forage consumed only provided adequate crude protein year around if green, herbaceous growth was available or shrubs made up large portions of the diet (Cable and Shumway 1966; Galt and others 1969; Hayer 1963). While cattle could meet their protein requirements over most of the year by selective grazing, seasonal animal weight changes were caused by seasonal changes in animal requirements (primarily associated with reproduction) and seasonal changes in the quantity and quality of forage (Ward 1975).

Later nutritional studies focused on Lehman lovegrass as it greatly increased in abundance on much of the SRER (Anable and others 1991). Nutritive values were reported from samples clipped seasonally and from heavily and lightly grazed patches (Abu-Zanat 1989; Osman 1980; Renken 1995). Both crude protein and in vitro dry matter digestibility were higher in Lehmann lovegrass samples from heavily grazed patches than from the adjacent lightly grazed areas (Renken 1995). Diet quality of cows grazing Lehmann lovegrass was also estimated (Ruyle and Rice 1996). Although standing biomass of Lehmann lovegrass is often nutritionally marginal, cattle were able to select green material with adequate crude protein and phosphorous to meet their needs throughout most of the year.

Grazing Distribution

Achieving adequate grazing distribution became an issue as stocking rates were slowly reduced on the SRER. Free-ranging livestock tend to concentrate grazing use near permanent water, resting areas, ridges, bottoms, and areas near trails. Forage utilization levels decrease with increasing distances from these sites (Reynolds and Martin 1968). Range management practices such as watering, salting, supplemental feeding, and fencing were all used on the SRER to improve grazing distribution.

Adding watering places was an early method to promote uniformity of forage use (Culley 1938b). Water hauling was also effective in improving grazing distribution, especially during drought conditions; however, under some situations this practice proved too costly (Bohning 1958a; Reynolds and Martin 1968). Controlling access to water within individual pastures was also used to rotate grazing. Martin and Ward (1970) demonstrated that utilization of perennial grasses near water could be reduced and herbage production increased using this technique.

Providing salt or salt meal was another common method to improve distribution of grazing (Bohning 1958b) albeit with mixed results (Culley 1938b). Placing salt or salt meal on remote parts of the range was found to increase utilization of perennial grasses in those locations, but did not significantly reduce use on areas closer to permanent water (Martin and Ward 1973).

Fencing to improve grazing distribution was also implemented on the SRER, and subdividing large pastures improved livestock handling and forage use patterns, resulting in increased calf crops (Reynolds and Martin 1968).

Stocking Strategies

Conceptual Considerations—From the earliest writings, researchers recognized that if overstocking was the problem, proper stocking was, at least in large part, the solution. As early as 1891, Toumey wrote, "Overfeeding a range has a tendency to kill out better grasses." He recognized that there were ecological and economic limits to which the range should be stocked and "beyond this limit… will be a detriment to the permanency of the range." Reducing stocking rates in order to get cattle numbers more in line with forage production was one of the first orders of business on the SRER (Culley 1937c).

As previously stated, the SRER was destocked from 1903 until about 1914 to allow for some degree of recovery from the extreme overuse suffered under the open range grazing policy for public lands. The SRER was grazed yearlong from 1915 until 1957 when seasonal grazing and grazing system research began.

Over the years a variety of stocking rates have been suggested for semidesert grassland ranges (table 1). Santa Rita researchers and managers recognized declining productivity coupled with a series of drought years and gradually reduced livestock numbers (table 2). Additionally, perceptions of conservative stocking and resulting moderate utilization changed over the years, desired levels of utilization being reduced from about 70 percent (derived from stubble height recommendations found in the archives) to the 40 percent recommended in various publications by Reynolds, Martin, and Cable during the 1960s and 1970s.

Stocking rates on the SRER averaged about 19 acres per Animal Unit Year (AUY) during 1915 until 1925, when they were reduced to about 44 acres per AUY due to historic overuse and declining forage productivity (Cable and Martin 1964). Utilization levels, however, remained high until, in 1956, stocking rates were reduced again in at least four pastures in an attempt to achieve an average 40-percent utilization over species and pastures, which was the stocking objective of the Cable and Martin study (table 2).

Stocking strategies became especially critical during frequent droughts. Experience indicated that each 10-year period brought at least 3 years of critically dry conditions (Canfield 1939). How best to provide continuous yearlong forage for a constant number of livestock became a stocking rate problem. On black grama ranges at the Jornado Experimental Range in southern New Mexico, Canfield (1939) reported that stocking rates of 22 acres per AUY, even though reduced from higher levels at the beginning of the study, were still too high to be maintained in drought years. Conservative stocking levels were recommended that would leave an additional 25 percent of the "useable grass of the average forage crop…ungrazed at the beginning of the new growing season." Presumably, this adjustment further reduced stocking rates to approximately 29 acres per AUY.

Table 1—Recommended stocking rates for native semidesert grassland in the Southwest.

Stocking rate acres per AUY[a]	Approximate location	Source
37	Semidesert grassland	Griffiths (1904)
50	Santa Rita foothills (approximately 4,000 ft)	Griffiths (1904)
20	Good pasture on Santa Rita Range Reserve	Wooton (1916)
25 to 45	General estimate for semidesert grassland	Ware 1939 (AWP)[b]
22	Black grama range on the Joranada	Canfield (1939)
20	Areas over 4,000 ft on the SRER	Bohning and Martin (1954)
25 to 50	High-elevation pastures on the SRER	Reynolds and Martin (1968)
50 to 100	Mid-elevation pastures on the SRER	Reynolds and Martin (1968)
60 to 160	Low-elevation pastures on the SRER	Reynolds and Martin (1968)

[a] Acres per Animal Unit Year.
[b] Unpublished document from the Arizona WPA Writer's Project.

Table 2—Actual stocking rates applied to various locations on the Santa Rita Experimental Range (SRER) in southern Arizona.

Stocking rate acres per AUY[a]	Years	Approximate location	Source
13.3	1908 to 1914	Averages for Ruelas, Proctor, and MacBeath, early ranchers on the SRER	Wooton 1916
19	1915 to 1925	Average stocking for pastures 1, 7, 8, and 10	Cable and Martin 1964
63	1926 to 1937	Average stocking for entire SRER	Culley 1937?
19	1922 to 1931	Average stocking for “a foothills pasture”	Reynolds 1950
30	1932 to 1941	Average stocking for “a foothills pasture”	Reynolds 1950
44	1941 to 1956	Average stocking for pastures 1, 7, 8, and 10	Cable and Martin 1964
23 to 63	1957 to 1966	Range of stocking for pastures 1, 7, 8, and 10	Cable and Martin 1964
20 to 43	1957 to 1966	Average stocking for pastures 1, 7, 8, and 10	Cable and Martin 1975
120	1957 to 1967	Average stocking for pastures 12B, 3, 2N, 5S, 5N, and 6B	Martin and Cable 1974
45	1972 to 1984	High-elevation, Block 1	Martin and Severson 1988
62	1972 to 1984	Mid-elevation, Block 2	Martin and Severson 1988
141	1972 to 1984	Low-elevation, Block 3	Martin and Severson 1988

[a] Acres per Animal Unit Year.

Reynolds (1954) applied this conservative philosophy in his classic discussion of drought and range management based mostly on data from the SRER, collected and organized by Matt Culley. Reynolds compared forage production and stocking rates during three 10-year periods (1922 to 1931, 1932 to 1941, and 1942 to 1951). He characterized drought severity during these periods, respectively, as slight, moderate, and severe. The stocking level was considered conservative during the entire 30-year period, and “was maintained about 20 percent below that which would have been possible based upon average forage production.” Based on a review of records, this stocking strategy probably resulted in an average utilization level of around 60 percent over the 30 years, a little higher during the early years, and a little lower later in the study. This variance was likely due to the diligence with which the stocking levels were actually adjusted. Relying on these long-term records, Reynolds recommended stocking rates that would “use about 40 percent of the average long-term forage production,” but also determined that stocking should be 40 percent below this average about 35 percent of the time “when droughts reach moderate and severe intensity.” In other words, during drought years, reduced production levels would provide less forage for consumption than 40 percent of the long-term average, even at relatively heavy utilization levels. He recognized that livestock operations needed to cull heavily in bad forage years while holding over yearling animals and perhaps purchasing other growing animals during good forage years. The basis of his stocking strategy appears to be aimed at the ability to maintain a base cow herd at a level that reduces the need to heavily destock in drought years.

For their 8-year grazing study in pastures 1, 7, 8, and 10, Cable and Martin (1964) carefully set stocking rates every October based on forage production during the previous summer in an attempt to achieve a 40-percent utilization objective. These calculations, based on Reid and others (1963), resulted in average stocking of 49 acres per AUY in range units 8 and 10, and 63 acres per AUY in units 1 and 7. The Reid and others regression approach to stocking requires a history of intensive data on herbage production and utilization, and was developed for stocking experimental pastures. However, in the Cable and Martin (1964) study, utilization varied yearly from about 30 percent to 65 percent, and use on individual species varied even more widely, even though animal numbers were adjusted annually. Arizona cottontop, plains bristlegrass and, surprisingly, Lehmann lovegrass were used most heavily, while one of the least utilized species was black grama. The high use levels for Lehmann lovegrass likely have less to do with palatability than relative forage abundance; the less abundant species were grazed the most. Overall, utilization levels achieved during this study allowed increases in grass cover over prior years when use was much heavier.

Other records also indicate that species composition of perennial grasses on the SRER has changed since about 1942 as stocking rates were reduced (Reynolds 1956; Rivers and Martin 1980). In 1942, a utilization objective of 50 percent of all the perennial grass herbage was considered conservative. However, actual utilization averaged higher than that between 1942 and 1957 (52, 54, and 58 percent on low-, middle-, and high-elevation pastures). From 1957 until 1966, the utilization objective was lowered to 40 percent of all of the perennial grass herbage, and the Reid and others (1963) basis for adjusting numbers was employed. Utilization “varied markedly” from year to year even though cattle numbers were adjusted each fall (Rivers and Martin 1980). However, over years and all perennial grass species, use at the upper elevation averaged 42 percent, well below the previous years, while use in the middle and lower elevation pastures averaged 49 percent. The more palatable midgrasses increased in composition up to 72 percent during this period.

Practical Considerations—Estimating grazing capacity for a range and making stocking rate adjustments to achieve utilization objectives are largely of conceptual interest; however, developing practical strategies to increase or reduce stocking from one year to the next can have tremendous logistic and economic consequences. Martin (1975c) clearly recognized these practical implications to range management recommendations and, using a plethora of data collected on the SRER, designed a simulation study to analyze “several strategies for coping with year-to-year changes in forage production” focused on ranch income. Records of forage production, utilization, and stocking rates for eight pastures over 29 years were used to compute "average proper stocking" (based on 40-percent utilization) and to determine the effect of various stocking strategies on cattle sales income at these levels. Stocking rate strategies included constant stocking at 100, 90, and 80 percent of average proper stocking. "Flexible stocking" allowed the number of animal units to fluctuate from 60 to 140 percent of the average proper stocking in accordance with forage production, and "limited flexible stocking" allowed fluctuations of 70 to 110 percent of average.

Under flexible stocking, two plans to reduce stocking were tested for culling in years when forage production was less than the year before. In the first strategy, these management scenarios sold, in order: (1) weaner calves normally held until yearlings, (2) replacement weaner heifers, (3) replacement heifers, and (4) older breeding cows. In the second strategy, old cows were sold first and replacement heifers last. To increase stocking, the scenarios held cows normally culled if the total number of bred cows was low, also held calves normally sold as weaners, and "purchased" additional stocker calves. The highest simulated average net sales resulted from constant stocking at 100 percent of the average level of proper stocking (the highest constant stocking rate tested) followed by net sales under flexible stocking (the flexible rate that allowed increases up to 140 percent of the average). However, Martin understood that the "hazards and high costs of overstocking" also should be considered. The risk of overstocking was evidenced by the fact that these two stocking levels, constant average and the flexible rate with the highest stocking, would result in overstocking almost half the time. The well-documented results of overstocking were manifest in future reduced productivity of perennial forage grasses, facts well known to Martin!

In Martin's analysis, the relative economic advantage of stocking cows and calves over yearlings depended largely on differences in weight and price per pound between calves and yearlings. Simulations showed that cow-calf units produced more income per animal unit of stocking than cow-yearling units at calf crops of 60 percent or better. Yearlings needed to be held over a full year to ensure they would weigh enough to justify keeping them. However, net sales per 100 animal units in flexible stocking of 120, 130, or 140 percent of average in the best forage years were only $100 to $200 greater than for constant stocking at 90 percent of the average proper stocking. Martin was "almost certain that stocking at 90 percent of the average will be more profitable in the long run" than stocking at any higher levels. This stocking rate, 90 percent of the long-term "average proper stocking" (which was calculated at 40-percent utilization) continues to be recommended for semidesert ranges today (Holechek and others 2003). Yet, actual stocking rates higher than these have maintained or improved forage grass stands on the Santa Rita.

Even though SRER researchers attempted to set stocking to achieve specific utilization standards each year, their efforts were surprisingly unsuccessful. Utilization levels varied yearly and by pasture in every long-term grazing study conducted on the SRER. As Martin wrote in 1975a, "stocking rates assume that utilization of perennial grasses over a period of years averages around 40 percent, but may range from as low as 20 percent to as high as 60 percent in individual years." He went on to say that "the carrying capacity of a range cannot be measured precisely." Grazing capacity estimates should be determined "by pasture tests under actual grazing use" (Talbot 1937). As Reynolds and Martin (1968) wrote, "each range should be stocked on its own merits." Only by stocking and monitoring utilization and plant community responses over time can actual grazing capacities be estimated and adjusted as environmental conditions dictate.

Estimating Utilization

"The key indicator of proper stocking is the intensity of use" (Martin 1975a), so methods to help adjust stocking rates accordingly needed to be developed and tested. The primary expression of stocking levels on range vegetation is "utilization," defined in 1944 as the degree to which animals have removed the current growth of herbage, expressed in percentage of growth within reach of livestock (Society of American Foresters 1944, as cited in Heady 1945). Measuring and interpreting utilization is "one of the most important phases of range management."

Humphrey stated in 1938 that during the 22 years (at that time) of regulated grazing on the SRER, "the aim has been to determine proper utilization." But to do this, the SRER researchers needed a way to improve the accuracy and meaning of utilization estimates. If not conceived on the SRER, the concept of utilization was certainly refined, and field methods were developed and applied as a major research effort there. In this way utilization levels on perennial grasses were estimated to determine stocking pressure.

Specifically, early SRER managers and researchers recognized certain fundamental concepts of utilization. The concepts of proper use, using key species as indicators of utilization on the range as a whole, and the variation in "proper use for a given key species" by range type, soils, and class of stock were summarized by Crafts and Wall in 1938. They clearly realized that "In order that the standards may be properly interpreted and applied, certain fundamental concepts of utilization must be recognized." They specified that utilization "should be determined at the end of the grazing season," in other words, fall on seasonal summer ranges and spring on yearlong or seasonal winter ranges.

Parker and Glendening (1942a) defined proper use as "the degree of grazing that will allow the more palatable forage plants to maintain density and vigor, prevent undue runoff and erosion," and proper use factors, recognized to be "an average for the type" were assigned to individual grass species. Proper use guides varied by range condition with higher levels permissible on ranges in better condition (Crafts 1938b; Parker and Glendening 1942a). Utilization was clearly to be determined "at the <u>end</u> of the grazing year or season" (emphasis in original Parker and Glendening manuscript).

Commonly, the very early observers merely recorded utilization in relation to 100-percent use, and ranges were not considered fully used until "all vegetation was grazed to the ground" (quote from unpublished field notes in SRER archive). However, later researchers soon developed progressively quantitative methods to estimate utilization. In Lister (1938a), "utilization figures represent the percentages grazed of the total plant height" for perennial grasses. Crafts (1938b) recognized that height and volume were not analogous and developed height-weight relationships for the various forage grasses as "a possible method for measuring volume utilization in the field." This method was adapted to field procedures using step or line transects by Parker and Glendening (1942b). A utilization gauge was developed to compute the percent of plant volume removed (Lommasson and Jenson 1943; Parker and Glendening 1942b). Pastures were divided into at least two utilization zones for sampling (Parker and Glendening 1942b), and the number of transects required was determined by the relative size of the zone. Utilization was estimated by species, and a weighted average based on the number of plants (called percent composition) was calculated for each zone. Then the percent of proper use was determined by "dividing actual percent use by the calculated percent proper" that was based on proper use factors assigned to each important, grazed species.

Canfield (1942a) proposed the line interception method to estimate utilization (and other "forage-plant inventory" attributes) as a field technique to "insure uniformly good results." Stubble heights and basal intercepts were recorded on the line, and each stubble height measurement was placed in a stubble height class adapted from Culley (1939) (SRER archives, unpublished data). Measurements were then converted to a weighted average height for each species (Canfield 1944a). A "short-cut" way to apply stubble height estimates was also described by Canfield (1942b, 1944b) for "the field man who has much work to do and little time to do it in." This procedure estimated only the amount of a grass stand grazed to a stubble height of 2 inches or less. Canfield suggested that a proper utilization level was reached when about 60 percent of the forage grasses had been grazed to a height of 2 inches.

Methods to estimate forage use on the SRER changed over time reflecting more conservative stocking levels and more intensive analysis (table 3). From 1920 to 1938, use was mapped during a general range reconnaissance by "percent of proper use" in seven percentage classes (SRER archives, unpublished field notes): (1) 0 to 30 percent, (2) 35 to 50 percent, (3) 55 to 65 percent, (4) 70 to 80 percent, (5) 85 to 90 percent, (6) 100 percent, (7) greater than 100 percent.

In the 1939 "Utilization survey report on the Santa Rita Experimental Range," Culley provided nine stubble height classes (table 3) that were combined with a line intercept method to estimate degree of use on individual grass species. This method was used until 1949, differing only slightly the last 3 years of use by locating transects at varying distances from water. In 1950, the method of basing utilization on the percentage of ungrazed plants (Roach 1950) was initiated. This then became the method of choice for most subsequent utilization surveys, including all pasture level grazing studies up to and including Martin and Severson (1988).

Grazing Management and Grazing Systems

Early range scientists commonly recommended some sort of seasonal rest (for example see Sampson 1919), and this was not lost on the Santa Rita researchers. Early research on the SRER, however, focused on reducing stocking rates and the effects of yearlong grazing. Lister and Canfield (1934) studied seasonal differences in cattle selection of grass species and found that different species were preferred in different seasons. Lister (1938b) noted that cattle preferred sideoats grama and Arizona cottontop during the summer, and curly mesquite, black grama, bush muhly, *Bouteloua chondrosioides* (H.B.K.) Benth. Ex S. Wats. (sprucetop grama), and slender grama were preferred during the fall and winter. *Bouteloua hirsute* Lag. (hairy grama) and *Lycurus setosus* (Nutt.) C. Reeder (wolftail) were chosen primarily in the spring. Lister and Canfield concluded, "Seasonal, selective grazing is the natural grazing system."

To properly stock a range grazed yearlong, this seasonal preference was to be coupled with seasonal production of forage species. Canfield (1938) applied this concept to black grama ranges on the Jornada Experimental Range in a system of grazing he called "semi-deferred." Semideferred

Table 3—Methods used to estimate utilization of perennial grasses on the Santa Rita Experimental Range in southern Arizona.

Years	Method used	Reference
1920 to 1938	General reconnaissance; use was mapped as percent of "proper use"	Unpublished field notes from archives
1939 to 1946	Line transects to estimate stubble height; these were placed into stubble height classes[a]	Canfield 1942a and b, Culley's unpublished field notes from archives
1947 to 1949	Same as above except line transects were located at several distances from permanent water	Parker and Glendening 1942b, unpublished field notes from archives
1950 to 1984	Pace transects to estimate the percent of ungrazed plants	Roach 1951

[a] Stubble height classes from Culley (1939) (unpublished document in SRER archives).

Class	Stubble height	Comments
1	1/2 inch or less	Very closely used
2	1/2 to 1 inch	Closely used
3	1 to 2 inches	Light overuse
4	2 to 4 inches	Generally conservative use
5	4 to 6 inches	Moderate use
6	6 to 8 inches	Light use
7	8 to 10+ inches	Light to no use
8	Ungrazed	

grazing provided yearlong use but applied “relatively light stocking during the summer grazing season and heavier stocking during fall, winter and spring months.” By regulating stocking in this manner, Canfield concluded, “both summer and winter forage plants receive their just proportions of use.”

Continuous yearlong grazing, however, especially at heavy stocking levels, was well known to alter native grass species composition and reduce forage production on Southwestern ranges (Canfield 1948; Martin 1972). This was especially true near waters with long histories of heavy use. Reducing stocking levels only partly solved this problem because heavy use persisted near permanent water sources. Rotating access to water on the SRER somewhat altered the pattern of heavy use if stocking rates were moderate and the “closed period” included the summer growing season (Martin and Ward 1970).

Under yearlong grazing, proper stocking rates should allow roughly 70 to 80 percent of the current year’s forage to remain after summer use (Lister and Canfield 1934; Talbot 1937). These levels were not the norm on southern Arizona ranges during the first half of the twentieth Century. Utilization surveys on the Santa Rita routinely reported average use well in excess of 70 percent until the 1940s when levels were reduced somewhat (SRER archives, unpublished documents). By this time, experience and empirical evidence conspired to cause reductions in recommended use levels on the SRER. Utilization levels of around 40 to 45 percent on perennial grasses were a common recommendation by mid-1950, however, surveys continued to document average use of over 50 percent on the SRER (SRER archives, unpublished documents). While stocking rates had received considerable attention by mid-century, the effects of grazing at different seasons had not yet been extensively studied in the Southwest.

Data from studies presented at the 1927 Annual Ranger Meeting (SRER archives, unpublished document) indicated that researchers were considering various timings of grazing early in the history of the SRER. Small pasture divisions were protected from grazing during various seasons, and these were compared with “yearlong overgrazing” and “conservative grazing.” It is evident that stocking was to achieve 100-percent use of “average forage production” except under conservative grazing where about 15 percent of the production was left ungrazed (85-percent utilization). Only under conservative yearlong stocking, even at this high level of utilization, did the “palatable forage grasses” make gains in plant density. Thus, level of stocking rather than seasonal rest was believed to be the primary factor preventing loss of forage species.

In later studies, Reynolds (1956) demonstrated similar, if not increased, recovery of cottontop on conservatively stocked pastures grazed yearlong compared to summer-deferred pastures. However, season of use continued to be investigated as a potential grazing management strategy. For example, Cable (1979) found that, over a 15 year period, dormant season grazing, even at high intensities (over 70 percent), had no detrimental influence on Arizona cottontop.

The comparison of seasonal grazing with yearlong grazing on a pasture scale began in earnest in July 1957 with the two 10-year studies, described fully by Martin and Cable (1974) and Cable and Martin (1975). The grazing treatments in the two studies were the same, November to April, May to October, and yearlong, but stocking was much heavier as described by Martin and Cable (table 2). The intent was to stock the seasonally grazed pastures at the same rate as the yearlong pastures, hence the number of animals were doubled in the seasonal units. As has proved the norm in large-scale grazing studies, weather was a dominant influence on vegetation responses. Additionally, initial plant community differences (perennial grass basal cover) among pastures persisted throughout the study. Although Cable and Martin (1964) concluded “moderate utilization of the perennial grasses combined with alternate-summer deferment of grazing resulted in marked range improvement,” and Reynolds and Martin (1968) reported seasonal deferment benefits were “evident in the preliminary results,” the 1974 analyses stated that such deferment “had no apparent beneficial effect,” and the 1975 paper stated “alternate-year summer deferment did not improve perennial grass production.”

Seasonal grazing did not result in improved animal or vegetation conditions when compared to yearlong grazing, perhaps partly due to more concentrated use limiting diet selection and somewhat higher utilization levels in the seasonally grazed pastures. Calf weights reported by Martin and Cable (1974) averaged somewhat higher from pastures grazed yearlong (415 poounds versus 396 pounds) and were significantly higher from the higher elevation pastures (446 pounds versus 365 pounds). These researchers continued to ponder the importance of seasonal rest, however, and several important hypotheses came from this study.

Martin and Cable determined that the November to April grazing treatment was not entirely a dormant season of grazing, but included a critical period of spring growth (February to April). Even though perennial semidesert grasses produce little growth during that period, it is the time when basal buds “break dormancy to initiate the culms that produce forage the following summer” (Cable 1975; Martin and Cable 1974). These researchers suspected that spring grazing was detrimental to forage production in the following summer, and this became the basis for further clipping studies (Martin 1973a) and, eventually, the foundation for the Santa Rita Grazing System (Martin 1973b; Martin and Severson 1988).

To more fully test this hypothesis, Martin (1973a) designed a series of small plot (20-ft square) grazing treatments to simulate 15 “rest-grazing schedules.” He accomplished these treatments during an 8-year study by rotating a series of panels to exclude grazing during certain periods at locations on “overgrazed range near permanent water” (Martin and Ward 1976). Due to such a location, average utilization was heavy, as high as 70 percent on plots that had been grazed continuously for the preceding 12 months or that had been rested in winter only. Of all the treatments tested, March through October rest, two years in three, resulted in greatest total perennial grass production. Grass densities were also highest in these plots, but not significantly greater than those with other combinations of rest.

Several of these alternate year seasonal rest treatments were compared in three different pastures in the Martin and Ward (1976) study. Seasons of rest were spring (March through June), summer (July through October), and winter (November through February), and were applied in various combinations using similar 20-ft-square exclosures as the earlier study. Perennial grass production was the measure of effectiveness and varied greatly among sites and years during the 7-year study. This variability masked any effects of the rest schedules on perennial grass production; however, March through October rest in alternate years was the best of the six treatments at two of the three sites in the experiment. This gave the researchers some hope that these results supported the earlier study, but they also suggested that perennial grass production might be too variable an attribute to test trends in "short term grazing studies" (Martin and Ward 1976).

From these studies and others, Martin (1973b, 1978b) proposed the three-pasture grazing system that became known as the Santa Rita Grazing System (table 4). The system was tested experimentally on the SRER at a pasture scale from 1972 to 1984 (Martin and Severson 1988). Study treatments included both a continuous yearlong treatment and the Santa Rita Grazing System, and were blocked by elevation roughly corresponding to the foothill, mesa, and transition units recognized by Canfield (1948) and Reynolds (1954). Utilization and densities of perennial grasses and canopy cover of shrubs were measured at two distances from water. Standing crop estimates were also determined each fall. Utilization was estimated by the ungrazed plant method (Roach 1950) and averaged about 50 percent for all treatments.

Plant densities and production varied in response to precipitation and elevation each year, but did not show measured positive responses to the grazing treatments. The pasture level study failed to duplicate the results of the previous small plot studies. Again, the researchers justified this nonresponse by citing site-specific variability in overall range conditions at the beginning of the study (higher densities of perennial grasses than the earlier study), relatively low grazing intensity, and climatic variability. Undaunted, Clark continued to fully believe and was not hesitant to write that 2 consecutive years of March through October rest should be included in semidesert grassland grazing systems (Martin 1975a).

In the early 1980s, a short-duration grazing system was briefly implemented, with a radial spoke fence design, where pasture fences radiate from a common water source. The demonstration never received the management attention necessary and was soon abandoned as a project.

Data Contingencies and Research Gaps

The Santa Rita researchers recognized there were limitations to their research imposed by the range itself. System-level influences were manifested in the results from most grazing studies on the SRER and continue to cloud the interpretation of these studies today. Soils and precipitation regimes were known to influence the potential for recovery from overgrazing and the ability of the vegetation to withstand grazing, concepts that became known as resilience and resistance. Researchers discovered early on that the elevational position on the SRER was directly related to precipitation and vegetation potential. Canfield (1948) and Reynolds (1954) organized this gradient into three units, the foothill unit (4,000 to 5,000 ft), the mesa unit (3,000 to 4,000 ft), and the transition unit (below 3,000 ft). Most subsequent grazing studies used similar distinctions as blocks in experimental designs.

The amount of precipitation received during a particular study was often the overriding influence on vegetation responses. Additionally, they learned that the plant community present at the beginning of a study also influenced the effects of the grazing treatments imposed. The Martin and Cable study (1974) began after the extremely dry seasons in 1956–1957, which undoubtedly influenced vegetation at the beginning of the study and, later, the subsequent treatment effects. Conservative stocking and seasonal grazing treatments were more likely to improve degraded plant communities, which were near water or in other areas of historically heavy grazing, than those communities less impacted by grazing. Species such as Rothrock grama and various threeawn grasses consistently increased in density and productivity in response to seasonal rest, while other grasses did not. The current shift to Lehmann lovegrass as the dominant grass in some pastures has no doubt changed potential ecosystem responses to grazing. Such factors continue to confound landscape-level grazing studies, even those designed as experiments with replicated pastures. Smaller plot, controlled studies have become the standard for rangeland research. The value of large studies should not be disregarded, however, and the SRER approach of combining small plots and pasture-level treatments is relevant today.

There are four areas of grazing effects that were not studied at the SRER and continue to be gaps in knowledge that limit science-based management of Southwestern rangelands. These are (1) riparian grazing, (2) combined prescribed burning and grazing, (3) the impacts of grazing on soils, and (4) grazing effects on endangered species. There is little or no riparian vegetation on the SRER, hence there was no opportunity to investigate this area. The impact of livestock grazing on endangered species has only recently achieved recognition as an important research topic. The SRER offers a particularly unique opportunity to investigate the influences of grazing on the *Corypantha scherri* var.

Table 4—Suggested grazing and rest schedules for the three-pasture Santa Rita grazing system (Martin 1973a).

	Year 1			Year 2			Year 3		
	November to February	March to June	July to October	November to February	March to June	July to October	November to February	March to June	July to October
Pasture 1	Rest	Graze	Graze	Rest	Rest	Rest	Graze	Rest	Rest
Pasture 2	Graze	Rest	Rest	Rest	Graze	Graze	Rest	Rest	Rest
Pasture 3	Rest	Rest	Rest	Graze	Rest	Rest	Rest	Graze	Graze

robustinspina (Schott & Engelmenn) L. Benson (Pima pineapple cactus), listed as an endangered plant species.

Fire and grazing regimes were discussed for years, but never actually applied to research designs due to logistic and other practical reasons. In addition, the limited amount of soils research is unusual. As described previously, the early observers recognized that the native bunchgrasses formed no sod, leaving the soil subject to trampling damage. Similarly, the presence of "washed soils" was recognized (Griffiths 1901). These conditions presumably resulted in reduced recovery and productive capacities compared to intact or undisturbed soils, but such research was not forthcoming.

Future Research Direction

Over 25 years ago, Martin (1975a) recommended shifting research emphasis from livestock production to using livestock as a tool to manage the range for stated objectives. He also recognized the emerging importance of open space and recreational opportunities and resource use demands from an increasingly urban population. These research shifts have never really occurred, yet the need for such information remains critical.

The past has certainly set the stage for future range livestock grazing research on the SRER. Existing, long-term data sets are available for careful analysis of grazing pressure gradients, including information from protected areas. Large, pasture-scale grazing treatments should be continued, but with a more integrated approach to range livestock production that considers vegetation and soil response, ranch management requirements and economics, and the role of ranching in planning and regulating urban growth. Reductions in the number of treatments and herds to consolidate resources, a re-examination of stocking rates, as well as the reinstitution of some of the traditional management practices should be considered, including adjusting animal numbers each fall, estimating annual utilization, and keeping a record of individual animal production. The potential for producing and marketing natural beef should also be investigated. In addition, landscape-level analyses to address questions about the sustainability of range livestock grazing in terms of nutrient flows, site potential, and watershed processes remain a priority.

Summary and Major Contributions

Research on the Santa Rita developed the concepts, methods, and tools to manage range livestock conservatively and therefore sustainably. The studies conducted and experience gained on the SRER provided the philosophy and working foundation for the Federal regulation of range livestock management in the Southwest, especially by the Forest Service. The research demonstrated that, if weather conditions are at all favorable and mesquite overstory is not a constraint, rangelands could recover from the effects of overgrazing and even improve while being conservatively grazed. Measurements of recovery included densities and productivity of palatable, native perennial grasses. In addition to precipitation and site potential, heavy stocking rates were identified as drivers of ecological range condition and livestock performance.

Seasonal rest, while considered important, actually proved to be of secondary value. However, spring through summer rest, for two years out of three was a deferred grazing system that was recommended and demonstrated, most convincingly in small plots, to improve overgrazed vegetation. Using this strategy in larger pastures, the most improvement that was measured was in species such as Rothrock grama and three-awn grasses rather than such midgrasses as Arizona cottontop and sideoats grama. Empirical observations, however, indicate that these plants also benefit from seasonal rest.

Recommended stocking rates for semidesert grasslands developed from SRER research were approximately 90 percent of average proper stocking based on 40-percent utilization, calculated from a running 10-year average forage production. It is interesting that, based on utilization surveys in the SRER archives, these recommended use levels never seemed to be achieved. Such conservative stocking recommendations appear to be made in order to reduce extremely heavy grazing in low forage production years and allow the maintenance of a relatively stable base cow herd over the long term. Of course, where Lehmann lovegrass now dominates the herbaceous plant community, higher stocking rates appear to be possible.

Utilization guidelines were shown to be just that, guidelines, and were never achieved every year. Many processes combined to produce variability in utilization estimates. Diet preference influenced degree of use on individual plant species, and grazing pressure varied over time and space resulting in uneven utilization patterns. Utilization levels were consistently inversely proportional to forage production even when livestock numbers were reduced to compensate for years with low precipitation. To provide some uniformity to the concept, utilization was estimated after the grazing season or in June on yearlong ranges, at several distances from water, and averaged over species, pasture, and year.

After grazing resumed in 1914, the SRER was never completely destocked, even during times of drought or in periods of drought recovery. In fact it was thought by some that ranges recovered more quickly under conservative grazing than when completely protected from grazing. SRER researchers recognized drought as a stocking rate problem and adjusted livestock numbers as necessary to accommodate reduced forage and to protect against ecological deterioration.

In conclusion, the concepts, principles, and practices developed on the SRER continue to be applied by range managers today. Much more is now known, of course, about plant physiological responses to grazing, animal behavior, and vegetation dynamics. However, it still behooves current range managers to integrate the lessons of the past with the knowledge of today as they continue the quest for sustainable rangeland livestock production that began on the Santa Rita Experimental Range.

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