ANNOTATED BIBLIOGRAPHY

On the Effects of Utilization Levels and Lower Stocking Rates on the Recovery of Rangelands

The following is an alphabetic listing of research reports and papers dealing with the effects of using utilization levels for grazing, and the effects of lower stocking rates on rangeland health. Under each heading is a brief synopsis of the report's primary findings.

Anderson,C (1995): Overgrazing destroys income-producing rangeland. Grass Roots December 1994-January 1995, 7.

<"There are many ranchers, that by overgrazing, are destroying their income-producing resource--their soil and associated plants." "Rainfall records for many years show that while below average years are frequent, nine out of ten years will receive at least 75% of the average rainfall. Most ranchers stock at a constant rate. Why not stock at 75% of what you estimate your stocking rate to be?"

"Think of stocking at 75% as 'rightsizing' of your ranching operation. Large corporations, such as IBM, have downsized their operations recently and have coined the term 'rightsizing.' We Americans have come to believe that more is better. Current trends in industry and government indicate that there is a new awakening that says more is not necessarily better.">

Anderson,EW (1969): Why proper grazing use? J. Range Management 22, 361-363.

<Proper grazing use is paramount in attaining efficiency of rangeland production. Numerous scientific studies provide the basic reasons for practicing proper use.>

Anderson,JE; Holte,KE (1981): Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. J. Range Management 34, 25-29.

<Data from permanent vegetation transects, established on the Idaho National Engineering Laboratory Site in 1950, were analyzed to determine what changes had taken place in the vegetation complex over the past 25 years in the absence of grazing by domestic livestock. Cover of shrubs and perennial grasses has nearly doubled. Shrub cover in 1975 was 154% greater than in 1950; this change was almost entirely due to increases in cover of big sagebrush between 1957 and 1965. Cover of perennial grasses increased exponentially over the 25-year period, from 0.28% in 1950 to 5.8% in 1975. This was paralleled by significant increases in density and distribution of the four most important grasses on the study area. The 20-fold increase in perennial grass cover has not been at the expense of the shrub overstory. There was no obvious correlation between trends for perennial grass cover and precipitation patterns. Rather, the exponential growth is believed to reflect the availability of seeds as formerly depleted populations increase in size. No evidence of seral replacement, as predicted by classical succession, was found. The data seem more consistent with the "initial floristics/relative stability" concepts of vegetation development.

It is interesting to note that the improvement that was observed was non-linear, with an obvious lag-phase. Little increase in perennial grass cover occurred between 1950 and 1965, at which time the cover began an exponential increase. The authors suggest that the general

pattern of recovery on arid rangelands may be a slow change during the first decade or so of rest followed by more rapid revegetation as previously depleted populations build up their size and seed production. Aridity or poor initial condition would tend to lengthen the time before noticeable improvement would be detected.>

Beale,IF; Orr,DM; Holmes,WE; Palmer,N; Evenson,CJ; Bowly,PS (1984): The effect of forage utilization levels on sheep production in the semi arid south west of Queensland. In: Proceedings of the 2nd International Rangeland Congress. (Eds: Joss,PJ; Lynch,PW; Williams,OB) Cambridge University Press, New York, 30.

<The authors tested the effects of sheep utilization levels of 10, 20, 30, 50, and 80% on animal production per unit area in semi-arid rangelands west of Queensland, Australia. They found that the optimum utilization rate appeared to be about 30%.>

<<An argument for conservative utilization levels on semi-arid rangelands.>>

Beetle,AA; Johnson,WM; Lang,RL; May,M; Smith,DR (1961): Effect of grazing intensity on cattle weights and vegetation at the Bighorn Experimental Pastures. University of Wyoming, Agricultural Experiment Station Bulletin 373. Laramie, Wyoming.

<Reports on a study conducted between 1951 and 1958. On plots with an average utilization ranging up to 40 or 45 percent the production increased during the period. Greatest increases occurred where utilization was the lightest. From these data it is evident that the production of Idaho fescue is related to the intensity with which the plants are utilized. The effect of utilization on production was greater on granitic soils than on sedimentary soils.>

Burkhardt,JW (1997): Grazing utilization limits: An ineffective management tool. Rangelands 19, 8-9.

<Author argues against using utilization limits as a management tool. He notes that grazing does not occur uniformly across the landscape nor throughout the season and that agency managers may inadvertently or intentionally select areas of livestock concentration or areas of special concern and close the allotment based on utilization in these areas.

Also notes that some measure utilization early in the growing season when its impossible to determine total standing crop (and therefore actual annual utilization)--this is more appropriately termed relative use (Frost et al. 1994). Maintains that plant growth during the rest of the growing season makes these early season measurements meaningless both biologically and practically.

Claims that both utilization and stubble height methods are "likely the least effective management tool." Notes that these were developed to manage season-long grazing and that proper season of use and rest are far more effective for dealing with most riparian grazing problems. He gives some management strategies for riparian improvement.>

Clary,WP (1995): Vegetation and soil responses to grazing simulation on riparian meadows. J. Range Management 48, 18-25.

<<10 cm or greater stubble heights appear to be required to ensure full biomass production in mountain meadow sedge communities. "If utilization guidelines are used, those rates that do not exceed 30% of the annual biomass production will likely maintain production the following

year." Grazing these communities "once annually to a 5-cm stubble height in the spring, or to a 10-cm stubble height in late summer, or at a utilization rate exceeding 30% of the total annual biomass production can reduce herbage production significantly." The recommendations in this paper apply only to maintaining or enhancing production and do not address the issues of streambank stability and channel maintenance.>>

Clary,WP; Webster,BF (1989): Managing grazing of riparian areas in the intermountain region. U.S. Dept. of Agriculture, Forest Service, Intermountain Research Station. General Technical Report Int-263, 11pp.

<The level of utilization occurring on a site--including riparian areas--is the most important consideration in the management of livestock grazing. Most riparian grazing results suggest that the specific grazing system used is not of dominant importance, but good management is. Control of use in the riparian area is key. Specifically designed grazing systems that control degree and timing of use in the riparian area can be very beneficial.

Recommends that a minimum herbage stubble height be present on all streamside areas at the end of the growing season, or at the end of the grazing season if grazing occurs after frost in the fall. The residual stubble or regrowth should be at least 4 to 6 inches in height to provide sufficient herbaceous forage biomass to meet the requirements of plant vigor maintenance, bank protection, and sediment entrapment.

To help achieve the stubble height goal: (1) On pastures grazed in spring only, utilization of streamside herbaceous growth should be limited to about 65 percent of the current growth, and livestock should normally be removed by July 15 to allow sufficient time for plant regrowth. On lower elevation pastures the appropriate spring removal date may be substantially earlier. (2) Streamside utilization of herbaceous forage in summer-grazed pastures should not exceed 40-50 percent of the current growth. (3) Fall use of streamside vegetation should not exceed about 30 percent, and the herbaceous stubble remaining at the end of the grazing period should meet the 4-6 inch criterion. (4) Season-long grazing should be limited to those situations where animal use and distribution can be carefully controlled, such as by the use of riparian or other special use pastures, and where the stubble height requirements can be met. (5) Special situations such as critical fisheries habitats or easily eroded streambanks may require stubble heights of greater than 6 inches. These are based on use in pastures in good to high ecological status.

They offer the following suggested initial actions: (1) Ecological status=early seral: for "A" and most "B" channel types, apply rest or the recommended riparian grazing management practices (above); for "B" channel types with medium to fine easily eroded soil materials and most "C" channel types, apply rest until the ecological status improves; (2) Ecological status=mid seral: for "A" and most "B" channel types, continue present management or apply the recommended grazing management practices; for "B" channel types with medium to fine easily eroded soil materials and most "C" channel types, apply the recommended grazing management practices; (3) Ecological status=late seral: For all types, continue current management or apply the recommended riparian grazing management practices; (4) Environmentally sensitive areas: a) For streambanks subject to early season grazing damage, where a combination of high soil moisture and fine soil texture results in streambanks susceptible to trampling damage, grazing may need to be delayed to a late season period; the herbaceous stubble height criterion would still apply; b) For habitats where T/E or sensitive species occur, or where streambanks/channels are highly erodible, the herbaceous stubble height criterion may need to be increased to greater than 6

inches; under extreme conditions the area may need permanent protection or, at a minimum, grazing may need to be removed for long periods.>

Clary,WP; Webster,BF (1990): Riparian grazing guidelines for the Intermountain Region. Rangelands 12, 209-212.

<<This paper basically summarizes Clary and Webster 1989.>>

Cook,CW (1977): Effects of season and intensity of use on desert vegetation. Utah Agricultural Experiment Station, Utah State University, Logan, Utah. Bulletin 483 - Reprinted March 1977.

<Clipping studies were conducted on seven dominant plant species on sagebrush-grass rangelands in western Utah. The species studied were the same as those reported in Cook and Child (1971). 75% defoliation was too severe for all species during all periods in all three phases of study and 50% defoliation was too severe for late spring and summer harvesting. It was concluded that 60% utilization was perhaps too severe for even winter use but 50% utilization in the winter would maintain vigor and sustained yield. 25% utilization was considered more reasonable for late spring and summer use than 30%.>

Cook,CW; Child,RD (1971): Recovery of desert plants in various states of vigor. J. Range Management 24, 339-343.

<Desert plants, when defoliated to the extent that vigor is even moderately reduced, require rather long periods of nonuse for complete restoration. Defoliation in the winter and again in the spring at even moderate intensities was considered deleterious to plant welfare. Late spring harvesting was significantly more harmful to plants than early spring harvesting.

Three browse species (black sagebrush, big sagebrush, and shadscale), two suffrutescent species (winterfat and Nuttall saltbush), and two grass species (Indian ricegrass and squirreltail) were clipped at three intensities (30, 60, and 90 percent of the available herbage) during four periods between 1959-1961. The four periods were winter only (about January 1), winter and again in spring (about January 1 and May 1), early spring only (about April 1), and late spring only (about May 1).

Plants judged to be in lowest vigor in 1962 were those clipped in the winter and again in late spring from 1959 to 1961. The three browse species that were clipped twice a year produced only about 18% as much crown cover as controls in 1962. The two suffrutescent species and Indian ricegrass that were previously clipped twice a year had about two-thirds as much crown cover as the controls in 1962. In 1968 the browse species from these same treatments were producing about 28% as much crown cover as the controls, the suffrutescent species had completely recovered, and grasses had from 55 to 76% recovery for squirreltail grass and Indian ricegrass, respectively.

Clipping only in late spring about May 1 was the second most severe treatment from the standpoint of reduction of vigor of desert forage plants. Past harvesting treatments during the winter only and during early spring only were less detrimental to the welfare of desert forage species than the other treatments.

Rate of recovery within a species was proportional to the state of vigor: the lower the vigor, the less rapid the recovery. It was found that desert plants clipped heavily during any season or harvested even moderately during late spring or twice a year, in winter and again in late spring, still differed significantly in vigor measurements from untreated plants even after seven years of protection.>

<<These findings have serious implications for rest-rotation grazing systems. The assumption that you can graze a species heavily or even moderately (when moderately is 60 percent as in this study) as long as you give it one growing season's rest is incorrect. Rather, proper attention must be given to level of utilization in *every* grazing period.>>

Cooper,HW (1953): Amounts of big sagebrush in plant communities near Tensleep, Wyoming as affected by grazing treatment. Ecology 34, 186-189.

<The author studied big sagebrush-grass rangeland. He concluded that when conservative grazing and occasional resting (deferring) or pastures is practiced on this site, climax grasses can largely replace big sagebrush without artificial aid. Further, under favorable weather and grazing conditions this displacement of big sagebrush by climax grasses can occur in a decade or less.>

Eckert,Jr,RE; Spencer,JS (1987): Growth and reproduction of grasses heavily grazed under rest-rotation management. J. Range Management 40, 156-159.

<The authors report on a study from 1975 to 1984 on a BLM allotment 48 km south of Winnemucca, Nevada. The most widespread community types on the allotment are Wyoming big sagebrush-Thurber needlegrass, Wyoming big sagebrush-bluebunch wheatgrass, and Wyoming big sagebrush-Idaho fescue. A 3-pasture rest rotation grazing system for grazing May through October was initiated in 1973. This system included periodic heavy use during the growing season, as a result of no reduction in stocking rate. The study's objective was to determine the effects of heavy forage use on the basal-area growth and frequency of occurrence of native bunchgrasses with and without sagebrush competition.

The amount of deferment and rest provided by the 3-pasture system was not sufficient to mitigate the effects of periodic overuse. Results of this study strongly implicate periodic heavy grazing during the growing season as a primary cause of restricted basal-area growth and lack of reproduction. These results support the contention that such grazing pressure can prevent range improvement in an otherwise appropriate rotation grazing system.

Management plans implemented without consideration of proper use should be examined and stocking rates adjusted, if necessary, to obtain utilization levels that allow plants of desirable species to respond to proper management.>

<<Another study illustrating the folly of implementing rest rotation grazing systems without using conservative stocking rates.>>

Ellison,L (1960): Influence of grazing on plant succession of rangelands. Botanical Review 26, 1-78.

<Classic paper summarizing the effects of grazing on the different rangelands of the West. Heavy grazing reduces plant species diversity, while moderate, light, or no grazing tends to

increase it, except for some humid Great Plains grasslands where moderate grazing appears to increase diversity over the ungrazed situation.>

Frost,WE; Smith,EL; Ogden,PR (1994): Utilization guidelines. Rangelands 16, 256-259.

<The authors discuss the difficulties in measuring utilization at times other than the end of the growing season. If utilization is measured before the end of the growing season, the total peak standing crop cannot yet be known. If utilization is estimated at this time by comparing grazed versus ungrazed areas, it will be overestimated.

The authors also note the difficulty in identifying "current year's growth" for some species, especially on evergreen shrubs. They recommend tailoring utilization guidelines for specific situations (i.e., time of use, what is measured, and how use is measured). They believe timing of grazing to be much more important than the percentage of biomass removed. They recommend a new term, such as relative utilization, be used to express utilization as it is currently being measured. Relative use guidelines can then be developed and tailored to specific situations which are reliable indices for making management decisions.>

Gray,JR (1968): Ranch economics. Iowa State University Press, Ames, Iowa.

<"Conservation of rangeland resources is implied mostly in terms of stocking rates, levels of grazing, or to use a more meaningful term, levels of utilization." "Usually 20 to 30 percent of the current annual growth of the major species present at the range site is considered 'light' grazing; 30-50 percent, 'moderate' grazing; and over 50 percent, 'heavy' grazing." Summarizing the results from 7 experiments in different rangelands, the author concluded that "*The net returns per acre usually are highest when the grazing rate is moderate*" [Emphasis in original.]>

Hart,RH; Clapp,S; Test,PS (1993): Grazing strategies, stocking rates, and frequency and intensity of grazing on western wheatgrass and blue grama. J. Range Management 46, 122-126.

<The authors examined the effects of stocking rates and grazing strategies in effecting change in the botanical composition of rangeland vegetation by altering the frequency and intensity of defoliation of individual plant species. Stocking rates have much greater potential than grazing systems for altering the frequency and intensity of defoliation and subsequent changes in botanical composition of range plant communities. Results of grazing studies support this conclusion.>

<<This paper should alert range managers to pay more attention to proper stocking rates (and grazing intensity, whether measured through residue, stubble heights, or utilization) and not rely on grazing systems alone to solve resource problems.>>

Hart,RH; Samuel,MJ; Waggoner,Jr,JW; Smith,MA (1989): Comparisons of grazing systems in Wyoming. Journal of Soil and Water Conservation, 344-347.

<The authors compared short-duration, rotationally deferred, and continuous grazing systems on blue grama-western wheatgrass range in high good condition at the High Plains Grasslands Research Station near Cheyenne, Wyoming. They found that stocking rate and distribution are much more important than rotation in determining the success of a grazing system.>

<<Shows that grazing systems will not compensate for stocking rates that are too high.>>

Heitschmidt,RK; Dowhower,SL; Pinchak,WE; Canon,SK (1989): Effects of stocking rate on quantity and quality of available forage in a southern mixed grass prairie. J. Range Management 42, 468-473.

<The authors studied the long-term (25 years) effects of heavy (HC) and moderate (MC) rates of stocking on quantity and quality of forage at the Texas Experimental Range. Quantity of available forage was greater in the MC than the HC treatment. Warm-season short grasses were favored under HC at the expense of warm-season mid grasses. Above-ground standing crop was greater in MC than HC. There was greater variation in cow/calf production in the HC than in the MC because forage availability was greater in the latter.>

Heitschmidt,RK; Walker,JW (1996): Grazing management: technology for sustaining rangeland ecosystems. Rangel. J. 18, 194-215.

<<"The long-term success or failure of all grazing strategies hinges around management's ability to control the frequency and severity of defoliation of individual plants over time and space." "Grazing management is a social process by virtue of its human component and the major social dilemmas encountered in grazed agroecosystems center around the impacts that ever-increasing human desires have on rangeland resources."

"...moderately stocked treatment was...more ecologically sustainable than heavily stocked treatment." "Ecological studies in these same treatments showed ecological condition, relative to seral stage, was higher in the MC than HC treatment and ecological trend was steady in MC treatment but declining in the HC treatment." "Thus, based strictly on economics, it can be concluded that the DR treatment was the most sustainable of the four treatments [HC, MC, DR, RC]."

"We believe both moderately stocked treatments (i.e., MC and DR) are socially more acceptable to society at large because they are aesthetically pleasing." Ecological condition "was fair in the HC treatment and good in all other treatment pastures. Thus, one might conclude that only the HC treatment would not be socially acceptable. But we would suggest that plant species composition does not impact society's acceptance of a given grazing practice nearly as much as amount of standing biomass, ground cover, number of faecal patties, etc.

We would argue, therefore, that neither the heavily stocked HC nor RG treatments would be very socially acceptable since standing crop and ground cover in both were substantially less than in the moderately stocked MC and DR treatments. If true, then it seems reasonable to conclude that current grazing technology requires moderate rates of stocking be employed to insure rangeland agriculture (i.e. grazing) is ecologically sound, economically viable, and socially acceptable."

Note: HC=Yearlong grazing at heavy stocking rates; MC=yearlong grazing at moderate stocking rates; DR=4 pasture, 3-herd deferred rotation grazing treatment stocked at a moderate rate; RG=16-pasture, 1-herd rotational grazing treatment stocked at a very heavy rate.>>

Herbel,CH (1974): A review of research related to development of grazing systems on native ranges of the western United States. Pp. 139-149 in: Plant Morphogenesis as the

Basis for Scientific Management of Range Resources; U.S. Department of Agriculture Miscellaneous Publication 1271. Washington, D.C.

<Research studies on grazing systems on native range in the 17 contiguous Western States were reviewed. Year-long continuous grazing was superior to seasonal grazing on the California annual rangelands. There was only limited success with any grazing scheme other than continuous on rangelands grazed only for a part of the year (seasonal ranges). The deferred-rotation system at Sonora, Texas, has resulted in sufficient range improvement to permit a 33-percent increase in stocking as compared to continuous grazing.

Most grazing studies have been established at a fixed stocking rate. Downward adjustments in livestock numbers were made only in severe drought. A fluctuating forage crop was given little thought in establishing grazing studies. This is probably one of the reasons many of the grazing studies have failed to show much improvement in range condition.>

<<This paper shows that stocking rate is likely the overriding factor in determining whether a grazing system works.>>

Holechek,J (1994): Adjusting stocking rate: distance to water and for slope. Western Beef Producer, 6.

<"Failure to adjust stocking rates for travel distance to water has resulted in considerable range degradation, particularly in the hot, arid rangelands of the southwestern United States. Several studies show cattle make little use of areas more than 2 miles from water."

Livestock performance suffers from having to travel great distances to water. "Research from Australia and on cold desert range in Oregon indicates major reductions in cattle weight gains when the distance exceeds one mile.

"Rugged topography is the second most important cause of poor livestock distribution on rangelands." "Livestock vary considerably in their willingness to use steep terrain. Large, heavy animals such as mature cattle or horses have difficulty in traversing steep rocky slopes. Cattle make little use of slopes over 10%."

Table 1. Suggested reductions in cattle grazing capacity with distances from water: 0-1 miles: No reduction; 1-2 miles: 50%; Over 2 miles: 100%.

Table 2. Suggested reductions in cattle grazing capacity for different slopes: 0-10%: No reduction; 11-30%: 30% reduction; 31-60%: 60% reduction; over 60%: 100% reduction.>

Holechek,J (1994): Arid rangeland stocking rates: key species considerations. Western Beef Producer, 7-8.

<"Generally when the key species and key area are considered properly used, the entire pasture is considered correctly used. In most cases, one to three plant species are used as key species. These plants should be abundant, productive, and palatable. They should provide the bulk of the forage for grazing animals within the pasture." Key species may differ with type of animal (e.g., blue grama is the key species for cattle on many New Mexico rangelands, while scarlet globemallow is the key species for antelope on these same rangelands).

"Under the key-species approach, secondary forage species such as muhly and threeawn will recieve light use, and key species (blue grama, dropseeds, bluestems) moderate use."

"Heavy use": Range has a "clipped" or mowed appearance. Over half of the fair and poor forage plants are used. All accessible parts of the range show use, and key areas are closely cropped. They may appear stripped if grazing is very severe. There is evidence of livestock trailing to forage. "Moderate use" (proper use): About one-half of the good and fair forage-value plants are used. There is little evidence of livestock trailing. Most of the accessible range shows some use. "Light use": Only choice plants and areas are used. There is no use of poor forage plants. The range appears practically undisturbed.

"On key areas, average stubble heights of 12 to 14 inches for tall grasses, 6 to 8 inches for mid grasses, and 2 to 3 inches for short grasses are recommended minimums."

Note: this summarizes parts of the 1993 Holechek paper, "Managing stocking rates to achieve range resource goals.">

Holechek,J (?): More about using "standards and guidelines" to decide stocking rates. Western Beef Producer, 52.

<"...while there is no substitute for experience in stocking individual ranges, how are range managers to make stocking rate decisions if they don't use some kind of quantitative procedure or guidelines? I have found stocking rate procedures based on utilization, distance from water and slope easy to explain to ranchers, environmentalists and the public at large. No doubt, these guidelines could in some cases result in light use of the range but in all cases they will avoid destructive grazing. If experience shows the range will carry more livestock, they can always be added. However, in arid areas, the effects of a few years of excessive stocking can be difficult to correct.">

Holechek,JL (1988): An approach for setting the stocking rate. Rangelands 10, 10-14.

<Summarizes the results of many research studies on utilization levels into a table. Examples are: 25%-35% for salt desert shrubland and true desert (Mojave); 30-40% for semidesert grassland and shrubland; 30-40% for sagebrush grassland; 50-60% for California annual grassland; 30-40% for coniferous forest; 30-40% for mountain shrubland; 30-40% for oak woodland. Ranges in good condition and/or grazed during the dormant season can withstand the higher utilization level, while those in poor condition or grazaed during the active growth period should receive the lower utilization level.

Gives a procedure for determining stocking rate based on knowledge of average forage production over a series of years, or estimates from a single year (paper discusses how to adjust for estimates in good and poor rainfall years--however, reliable estimates are probably not possible if precipitation deviates by more than 50% of the average annual ppt.). Based on the production estimate and the allowable use (obtained from the table discussed above), an initial stocking rate is determined. This stocking rate is then reduced based on percent slope (0-10%: no reduction; 11-30%: 30% reduction; 31-60%: 60% reduction; over 60%: 100% reduction) and distance from water (0-1 mile: no reduction; 1-2 miles: 50% reduction; more than 2 miles: 100% reduction).>

Holechek,JL (1991): Policy changes on federal rangelands: A perspective, or A Wall Street perspective on management of federal rangelands. Invited paper presented to the National Public Lands Advisory Council, November 19,1991, Holiday Inn, Golden, CO.

<Although heavy grazing may be more profitable than conservative grazing for a few years, in the long run (5 to 10 years) it gives a much lower rate of return and greatly increases financial risk (a table is included that demonstrates this for most U.S. and some Australian range types). Most range conservationists in BLM and other federal agencies tend to overrate the benefits of rotational grazing schemes such as short-duration or rest-rotation and underrate the benefits of a conservative stocking rate in conjunction with conventional livestock distribution practices such as water development. Numerous studies show that minimum residues are necessary to maintain soil stability, vegetation productivity, and wildlife habitat (Pieper and Heitschmidt 1988). Heavy stocking rates prevent range improvement under an otherwise appropriate grazing strategy (Eckert and Spencer 1986, 1987; Bryant et al. 1989; Taylor 1989). Rotational grazing schemes in conjunction with heavy stocking rates adversely impact livestock performance and financial returns the same as under heavy continuous grazing (Quigley et al. 1984; Heitschmidt 1986; Taylor 1986; Hart et al. 1988). Agrees with Pieper and Heitschmidt 1988 that "stocking rate is and always will be the major factor affecting degradation of rangeland resources."

Cites the work of Van Poollen and Lacey (1979) that found that herbage production on the average increased only by about 13% when rotational grazing systems were implemented at a moderate stocking rate. Increases, however, were larger (35% and 27%) when continuous livestock use was reduced from heavy to moderate and moderate to light, respectively. None of the more recent research on rotational grazing systems contradicts their findings. Although federal agencies should encourage ranchers to use rotational grazing strategies, these schemes should not be used as a justification for grazing practices that leave inadequate residues for soil, vegetation, and wildlife.

Provides a table of utilization guidelines similar to the one in Holechek 1988 and Holechek et al. 1998.>

Holechek,JL (1991): Chihuahuan Desert rangeland, livestock grazing, and sustainability. Rangelands 13, 115-120.

<Vegetation degradation by overgrazing occurs more quickly and recovery is much slower for desert compared to humid ranges. For example, in the more humid shortgrass ranges of northeastern New Mexico (12-16 inches average rainfall) vegetation recovery from severe overgrazing is almost always reversible and requires less than 10 years. By contrast, in the Chihuahuan desert areas of southern New Mexico (8-11 inches average rainfall) recovery of forage species after severe degradation has been almost nonexistent even after 20 or more years of complete rest. A much more conservative grazing strategy is needed to sustain the latter rangelands. Long-term studies from the College Ranch and Jornada Experimental Ranges near Las Cruces show that livestock grazing is sustainable in the Chihuahuan Desert, provided that the stocking rates used remove, on the average, about one third of the perennial grass production each year. Higher use than this results in deterioration of soil and vegetation resources.

Production is higher and wildlife diversity is higher on the moderately grazed (about 30% use) rangelands than on either ungrazed or more heavily grazed rangelands of the Chihuahuan Desert. Stocking rate reductions are much more effective than rotational grazing schemes in promoting recovery of overgrazed ranges. Because of irreversible soil loss and brush invasion, large areas

of Chihuahuan Desert rangelands will not improve without extensive brush control (coupled with proper grazing management).>

Holechek,JL (1992): Financial benefits of range management practices in the Chihuahuan Desert. Rangelands 14, 279-283.

<The management strategy that has proven most effective on Chihuahuan Desert rangelands, based on several studies, is to use a conservative stocking rate (30 to 35% use of forage), a continuous grazing system, a maximum watering point spacing of 2 to 3 miles apart, an intensive replacement heifer management program, and intensive breeding program, almost no supplemental feed inputs other than a salt/mineral mix on the mature cow herd, and partial confinement of the herd during periods of severe drought.

The conservative stocking rate is a critical factor in the superior vegetation, livestock, and economic performance on the College Ranch compared to surrounding ranges. Early long-term studies by Paulsen and Ares (1962) on the Journada Experimental Range and by Valentine (1970) on the College Ranch showed Chihuahuan Desert upland ranges had superior forage productivity under 30 to 40% use levels compared with those that were heavier. Over a 24-year period a combination of continuous grazing and conservative stocking on the College Ranch has tripled forage production, increased range condition from low fair to high good, improved wildlife habitat, and given superior cattle performance. Under this strategy a stocking rate increase of 40% (165 to 120 ac/AU) has been possible with no sacrifice in cattle performance or increase in degree of forage plant use.>

Holechek,JL (1993): Managing stocking rates to achieve range resource goals. In: Managing livestock stocking rates on rangeland. Proceedings of a symposium. (Eds: Cox,JR; Cadenhead,JF) Department of Rangeland Ecology and Management, Texas Agricultural Extension Service, Texas A&M University, College Station, Texas, 10-28.

<Residue is important to protect the soil and to protect key forage plants from extreme temperatures and destruction of growing points in the crown by insects, rodents, and pathogens (Sauer 1978; Sneva 1980). "Heavy defoliation during dormancy reduces herbage production almost as much as during active growth (Cook 1971)." "Ranges managed to maintain critical levels of residue show quicker recovery after the drought than those that have been heavily denuded."

"Heavy stocking rate rapidly decreases forage production in desert areas and gradually reduces forage production in humid ranges. These effects are more reversible and lower in magnitude on humid ranges." Cites Van Poollen and Lacey (1979): based on survey of literature they found average increases of 35% and 27% when continuous livestock use was reduced from heavy to moderate and moderate to light, respectively. "One of the cheapest ways to increase forage production on most ranges is to reduce stocking rate."

Grazing studies in the more humid central Great Plains (Klipple and Bement 1961) concluded most of the improvement in forage production from light grazing occurs during the first five to seven years. "However, on desert ranges the benefits of conservative stocking tend to accumulate and are greatest after a 5- to 10-year period (Holechek 1991). This is because rate of range recovery is strongly associated with amount of rainfall, and therefore, is relatively slow in the desert." "In arid shrubland ranges of the Southwest, light grazing can be a useful means of improving forage production during the early stages of range deterioration if desirable forages

are still present but in low vigor. However, light grazing has shown low potential for recovery of highly deteriorated, brush-infested ranges."

Although most stocking rate studies have used percent utilization of forage species to measure grazing intensity, standing crop (dry matter) measurements are the most useful for management decisions. "On year-long ranges most decisions regarding adjustment in stocking rates are made at the end of the growing season in the fall. After the standing crop is estimated, animal numbers can be adjusted so that a minimum residue of dry matter remains just prior to the average time when growth is initiated the following year." Gives guidelines for minimum residues on different Texas range types.

"Generally when the key species and key area are considered properly used, the entire pasture is considered correctly used. In most cases, one to three plant species are used as key species. These plants should be abundant, productive, and palatable. They should provide the bulk of the forage for grazing animals within the pasture." Key species may differ with type of animal (e.g., sideoats grama is a key species for cattle on many Texas rangelands, but the key species for whitetailed deer is live oak on these same rangelands). "Under the key-species approach, secondary forage species such as curly mesquite and threeawn will recieve light use, and key species (sideoats grama, Texas winterfat, little bluestem) will receive moderate use."

"Heavy use": Range has a "clipped" or mowed appearance. Over half of the fair and poor forage plants are used. All accessible parts of the range show use, and key areas are closely cropped. They may appear stripped if grazing is very severe. There is evidence of livestock trailing to forage. "Moderate use" (proper use): About one-half of the good and fair forage-value plants are used. There is little evidence of livestock trailing. Most of the accessible range shows some use. "Light use": Only choice plants and areas are used. There is no use of poor forage plants. The range appears practically undisturbed. "On key areas, average stubble heights of 12 to 14 inches for tall grasses, 6 to 8 inches for mid grasses, and 2 to 3 inches for short grasses are recommended minimums."

Discusses stocking rate adjustments for slope and distance from water. These are the same as given in Holechek 1988.

Discusses three methods of setting stocking rate. Found that the Holechek (1988) and Troxel and White (1989) procedures give more reliable stocking rate estimates than the SCS guidelines. Holechek (1988) concluded that in years of average or above average precipitation about 50 percent of the current year's forage production could be consumed by livestock in the more humid ranges (e.g., southern pine forest, tall grass prairie), 40-45% on mid-grass and shortgrass ranges, and 30-35% on desert ranges. Partial or complete destocking is required during droughts (75% or less of average annual ppt.) to avoid breaching critical residues. On most Texas ranges this would be necessary in 3-4 years out of every 10. The Troxel and White (1989) procedure is more conservative. It allocates 25% of current year forage production to livestock, 25% to natural disappearance (insects, wildlife, weathering), and 50% is left for site protection. On most western ranges partial or complete destocking would be necessary in only about 3-4 years out of 20 using this method.>

Holechek,JL (1993): Policy changes on federal rangelands: A perspective. Journal of Soil and Water Conservation May-June, 166-174.

<The author suggests the following policy changes on federal rangelands for the 1990s and beyond: (1) option of grazing privilege purchase from permittees in heavily urbanized areas; (2) promotion of conservative stocking rates with conservative grazing fees as an incentive; (3) active management of custodial allotments by BLM; (4) allow permittees to exercise allotment vacancy if grazing fees are paid; (5) integration of aesthetic values and wildlife needs into brush control projects; and (6) fees for recreational use of all federal rangelands. With respect to (2) he notes that most BLM lands are still stocked on the heavy side of moderate with the goal of 50 percent forage use. While this works well in the flat, humid regions of the Great Plains and Southeast, it causes range deterioration in the rugged, arid ranges of the West. Research shows stocking rates that involve 30 to 40 percent forage use will enhance range recovery, maintain adequate soil resources, and give the highest long term economic returns with the least risk on nearly all the western range types. With respect to (3) the author notes that a number of large allotments have been placed by BLM into the custodial category because of low condition or potential; in his opinion this is not a justification for practices that are ecologically and economically unsound.>

Holechek,JL (1994): Financial returns from different grazing management systems in New Mexico. Rangelands 16, 237-240.

<Moderate (40-45% utilization) continuous grazing appears more profitable and less risky than heavy (utilization 60-65%) continuous grazing or best pasture rotation grazing on shortgrass range in the central mountains of New Mexico. Moderate continuous grazing resulted in fairly stable range condition rated good using the ecological climax approach. Heavy continuous grazing lowered both range condition and forage production compared to moderate continuous grazing.

The best pasture rotational grazing system allowed a 25% higher stocking rate than moderate continuous grazing while improving range condition and increasing forage on the pastures where it was applied compared to moderate and heavy continuous grazing. It was financially unsound on a short term basis (10 years) because of reduced cattle performance and the financing costs associated with extra cattle and fence.>

Holechek,JL (1996): Financial returns and range condition on southern New Mexico ranches. Rangelands 18, 52-56.

<"Forage production and financial returns were evaluated over a 7 year period on New Mexico Chihuahuan desert ranches in poor, fair, good, and excellent ecological condition. Both forage production and net financial returns were greatest on excellent condition ranges and lowest on those in poor condition. Maintaining Chihuahuan desert rangelands in high good ecological condition gives a good balance between provision of forage for livestock and maintaining habitat for desirable wildlife. Removal of about one third of the annual production of primary perennial forage grasses will permit most Chihuahuan desert ranges to improve from fair to high good condition.">

Holechek,JL; Hess,K Jr (1995): Government policy influences on rangeland conditions in the United States: A case example. Environmental Monitoring and Assessment 37, 179-187.

<“Since the early 1970s the Bureau of Land Management (BLM) and the Forest Service have emphasized the monitoring approach in managing their rangelands. After a 5-year period of intensive monitoring, stocking rate and other management actions are typically adjusted,

depending on whether a definite downward or upward trend in range condition is observed. Examining the Afton Allotment on BLM land in southcentral New Mexico, we demonstrate serious flaws in the monitoring approach and other BLM grazing policies. Monitoring reflects past management but does not consider the future. Perverse incentives for permittees to maximize permit value rather than sustain the forage base still remain in place. The "Range Reform '94" proposals by the U.S. Department of the Interior do not address these incentives and other flaws in public land policy. We would reform federal grazing land policy by coupling grazing fees to grazing intensity. Ranchers choosing conservative sustainable grazing intensities would pay low fees, whereas those choosing heavy intensities would be charged higher rates. We would also implement other reforms: making livestock grazing permits transferable to other uses, discontinuing subsidies, eliminating restrictions on nonuse, offering incentives for public land investment, and establishing a biodiversity fund.">

Holechek,JL; Pieper,RD (1992): Estimation of stocking rate on New Mexico rangelands. Journal of Soil and Water Conservation 47, 116-118.

<In this study, six stocking rate procedures were compared using long-term data from moderately (sustainably) stocked Chihuahuan desert and shortgrass prairie experimental ranges in New Mexico. Without adjustment for distance from water and for slope, all procedures gave stocking rate estimates much heavier than the ranges actually carried. A quantitative stocking rate procedure that bases guidelines on available research relative to forage utilization, forage intake, adjustment for distance from water, and adjustment for slope underestimated stocking rate by an average of 10%. It appears this procedure can provide reasonable stocking rate estimates for most western U.S. rangelands, providing reliable data are available on the standing crop of the key forage species.

See the abstract for Holechek (1988), An approach for setting the stocking rate, for a discussion of the method.>

Holechek,JL; Pieper,RD; Herbel,CH (1998): Range management: principles and practices. 3rd ed. Prentice-Hall, Inc., Upper Saddle River, New Jersey. 542 pages.

<This range textbook incorporates most of the information provided in Holechek's papers on utilization and residue (e.g., Holechek 1988, 1991, 1993). In addition to providing tables on recommended utilization levels, productivity, and livestock performance for most U.S. rangelands, the book provides a table on recommended stubble heights for many of the common rangeland grasses.>

Holechek,JL; Stephenson,T (1983): Comparison of big sagebrush vegetation in northcentral New Mexico under moderately grazed and grazing excluded conditions. J. Range Management 35, 455-456.

<The authors examined the vegetation inside and outside a 22-year-old exclosure on big sagebrush rangeland near Taos, New Mexico. They found that elimination of grazing had little effect on vegetation composition on the two sites studied. These results are consistent with other studies that show recovery of depleted rangelands is slow to nonexistent in arid environments.>

<<Demonstrates that rangelands in poor condition (i.e., with very few to no perennial grass or forb understory) may have crossed a threshold over which there will be no return without technological inputs.>>

Holechek,JL; Tembo,A; Daniel,A; Fusco,MJ; Cardenas,M (1994): Long-term grazing influences on Chihuahuan Desert rangeland. Southwestern Naturalist 39, 342-349.

<Vegetation composition and forage productivity were studied on two Chihuahuan Desert ranges with different management histories. They involved the conservatively grazed New Mexico State University College Ranch, and adjoining intermediately grazed BLM ranges north of Las Cruces in southcentral New Mexico. Conservative and intermediate grazing involved about 30 and 50% average use by livestock of the key forage species, respectively.

Our data indicate that some mesquite-dominated ranges in the Chihuahuan Desert are responsive to both favorable rainfall and conservative stocking if residual perennial grasses remain, and that livestock grazing is sustainable under utilization levels that involve removal of one-third of the current year's growth of key forage species (black grama, dropseeds, threeawns). On coarse sandy soils with a high canopy cover of honey mesquite, brush control may be necessary to initiate range recovery.>

<<Proper utilization of these rangelands is about 30%, not 50% as practiced on BLM rangelands.>>

Holscher,CE; Woolfolk,EJ (1953): Forage utilization by cattle on northern Great Plains ranges. U.S. Department of Agriculture Circular 918. Washington, D.C.

<Both summer and winter utilization by cattle was investigated under heavy, moderate, and light stocking rates. Two replicate pastures were assigned to each stocking rate in separate winter and summer range areas. Utilization measurements were taken on several key species: bluestem wheatgrass (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), needle-and-thread (*Stipa comata*), buffalograss (*Buchloe dactyloides*), threadleaf sedge (*Carex filifolia*), silver sagebrush (*Artemisia cana*), and black greasewood (*Sarcobatus vermiculatus*). These measurements included grazed stubble heights, the number of plants grazed (plants of blue grama, needle-and-thread, and threadleaf sedge were not recorded as being grazed unless the herbage above 50% or more of the basal area had been removed), and the amount by weight of herbage removed. The study took place from 1939-1945 at the U.S. Range Livestock Experiment Station near Miles City, Montana.

Graphs showing percent of plant weight removed at different stubble heights are given for threadleaf sedge, blue grama, needle-and-thread, and bluestem wheatgrass. Stubble heights, percent of plants grazed, and utilization (weight of forage removed) are all related in a table. A guide to proper utilization of the major forage species is given in terms of plants grazed by range subtype (Upland subtype, Hills subtype, and Bottom subtype). The recommended percent of plants grazed for bluestem wheatgrass is 55% for the Upland and Hills subtype and 75% for the Bottom subtype. This corresponds to utilization levels of 30-35% and about 40%, respectively. The recommended percent of plants grazed for blue grama is 40%, 45%, and 65% for the Upland, Hills, and Bottom subtypes, respectively. These correspond to utilization levels of slightly less than 25%, about 28%, and somewhat less than 40%, respectively. Recommended percent of plants grazed for needle-and-thread is 55% and 60% for the Upland and Hills subtypes, respectively (the plant doesn't occur much in the Bottom subtype). These correspond to utilization levels of about 40% in both cases.>

<<This is an excellent paper that can be used to help relate stubble heights of key species to percent of plant weight removed>>

Houston,WR; Woodward,RR (1966): Effects of stocking rates on range vegetation and beef cattle production in the northern Great Plains. U.S. Department of Agriculture Technical Bulletin 1357. Agricultural Research Service, Washington, D.C.

<The data on utilization of vegetation by weight showed lower levels of utilization than those in other western range areas commonly associated with maintaining range and livestock productivity. Apparently, under the conditions of this study, the long-term average utilization of both western wheatgrass and needle-and-thread grass should not have exceeded 33 to 37 percent by weight for optimum productivity of the range resource and livestock using it.

The results indicated here on one major site show the most rapid and greatest total-plant growth under the lightest stocking levels. The range-condition classification of 1958 showed the three most heavily stocked pastures on the summer range at about the same reduced level of range condition. However, on the three most lightly stocked summer pastures a rapid increase in range condition with decreased stocking levels was evident.>

Hughes,LE (1982): A grazing system in the Mohave Desert. Rangelands 4, 256-257.

<A grazing system implemented in 1969 in the Beaver Dam Slope Allotment in the Mojave Desert was unsuccessful in improving conditions over a 10-year period at the utilization levels experienced. Although the 10-year average utilization of the perennial forage was light--around 30 to 35%--the high utilization (above 50%) that occurred in some of the 10 years harmed the desired grasses even when followed with rest from grazing. There is little a manager can do to bring perennial grass back from occasional years of heavy utilization in arid regions.

Managers should look to good management through seasons of use and holding utilization within safe limits--below 50%--on all years.>

Hughes,LE (1990): Twenty years of rest-rotation grazing on the Arizona Strip--an observation. Rangelands 12, 173-176.

<Based on 20 years of observation in the BLM Arizona Strip District, it was found that rest rotation grazing did not result in improvement of key species except where utilization levels in grazed pastures were below 50%. For example, on the Beaver Dam Slope allotment, downward trends were recorded between 1970-1982 at average utilization levels of 36% (range 10-70%), while this same allotment showed an upward trend from 1981-1989 at average utilization levels of 22% (range 11 to 34%).>

Hyder,DN (1953): Grazing capacity as related to range condition. Journal of Forestry 51, 206.

<The author concluded that on sagebrush-bunchgrass range in southeastern Oregon "although 50 percent utilization is generally considered to be moderate, it probably represents excessive cropping on the range under consideration because of the large proportion of poor and fair range condition." States that the amount of residue left at the close of the grazing system should be 160 pounds/acre.>

<<An argument for utilization levels in the neighborhood of 30-40% for most sagebrush-grass rangelands.>>

Jasmer,GE; Holechek,JL (1984): Determining grazing intensity on rangeland. Journal of Soil and Water Conservation January-February, 32-35.

<Reviews different methods of estimating utilization, residue, and stubble heights. Recommends using residue and stubble heights instead of utilization to evaluate grazing intensity. Two advantages of residue (including stubble height) methods are 1) managers can be trained much more easily to estimate residue visually than to estimate percent use, and 2) grazing intensity data between years and locations are more comparable.

Although guidelines concerning minimum residue and stubble heights are not available for most range types, they probably could be determined from the literature available. Guidelines already exist for the California annual grassland type (500 to 2500 pounds per acre, depending on site, Bartolome et al 1981, Hooper and Heady 1970), for blue grama range in Colorado (300 pounds per acre, Bement 1969), and for big sagebrush range in southeastern Oregon (160 pounds per acre, Hyder 1953).

Best means of evaluating grazing intensity for ranchers and others who must make routine management decisions may well be a general reconnaissance procedure. Ocular estimates of herbage residue are accurate and repeatable if the observer has some previous training. Where quantitative residue data are required, the best procedure appears to be the weight-estimate-by-plot method of double sampling.>

<<Excellent review of literature on measuring utilization>>

Johnson,WM (1953): Effect of grazing intensity upon vegetation and cattle gains on ponderosa pine-bunchgrass ranges of the front range of Colorado. U.S. Department of Agriculture Circular 929. Washington, D.C.

<Reports on a study conducted in central Colorado in an area representative of ponderosa pine ranges in the Front Range of the Rocky Mountains. The average herbage production increased on the moderately and lightly grazed grassland and was maintained on the moderately and lightly grazed open timber. In contrast, average herbage production decreased greatly in both the grassland and open timber on areas that received heavy grazing. Light grazing=10-20% of grass and sedge herbage removed; moderate grazing=30-40%; heavy grazing=50% or more>

Klipple,GE; Bement,RE (1961): Light grazing--is it economically feasible as a range improvement practice? J. Range Management 14, 57-62.

<The authors examine the results of 3 studies and conclude that light grazing is a cost-effective range improvement strategy for livestock operators and managers, especially on ranges that have not become depleted. They note, however, that light grazing alone cannot improve rangelands where competing undesirable vegetation dominates.>

Klipple,GE; Costello,DF (1960): Vegetation and cattle responses to different intensities of grazing on short-grass ranges in the central Great Plains. U.S. Department of Agriculture Technical Bulletin No. 1216. Washington, D.C.

<Reports on a study conducted from 1940 to 1953 on the Central Plains Experimental Range in northeastern Colorado. All four pastures under heavy grazing dropped two or more grades in range condition from 1942 to 1953. Two of the four pastures under moderate use held the same grade, while the other two improved two grades in range condition. All four light-use pastures improved in range condition. Heavy use=about 60% by weight of current growth grazed by end of the 6-month grazing season; moderate use=about 40%; light use=about 20%.

60% utilization was too heavy, either for maintaining satisfactory range condition or making best gains by the cattle. With 40% utilization, ample forage was available to maintain the cattle in thrifty condition all season. Production by the dominant grasses was maintained, highly palatable plants usually survived, and the general condition of the range was maintained or improved. Where less than 30% was grazed, cattle had access to surplus forage at all times. Highly palatable species like needle-and-thread and winterfat increased in frequency of occurrence and dominant grasses increased in vigor and yield.>

<<The summary includes comments on the appearance of the range under different utilization levels>>

Lacey,JR; Van Poollen,HW (1981): Comparison of herbage production on moderately grazed and ungrazed western ranges. J. Range Management 34, 210-212.

<The authors examined the results of 20 published grazing studies to see whether there was a difference between the total amount of herbage produced on ungrazed as opposed to moderately grazed Western ranges. They found that herbage production averaged 68 +/- 46% higher when plots were protected from a moderate level of livestock grazing. Herbage production of individual plants averaged 59 +/- 50% higher when they were protected, rather than clipped at a moderate level of use. This contradicts several published opinions that moderate grazing is beneficial when compared to no grazing.>

Lang,RL; Barnes,OK; Rauzi,F (1956): Shortgrass range: grazing effects on vegetation and sheep gains. Vol. Bulletin 343. Wyoming Agricultural Experiment Station, Laramie, Wyoming.

<Reports on a 10-year grazing study, conducted between 1945-1954 on native shortgrass range in southeastern Wyoming. Principal objectives were to determine the effects of 3 degrees of forage utilization on the botanical composition of the vegetation and the pounds of gain per head and per acre on sheep. Criteria for degree of utilization were average leaf heights of blue grama: 1.2 inches=lightly used; 0.9 inches=moderately utilized; 0.6 inches=heavily grazed. The four major grass species (blue grama, buffalograss, western wheatgrass, and needleandthreadgrass) responded differently to grazing pressure. Blue grama decreased on the ordinary upland site but increased on the slope site under heavy grazing. Buffalograss increased on the ordinary upland and dry bottom sites of the heavily utilized pastures but remained about constant on the slope site. Western wheatgrass responded to grazing pressure by decreasing on all sites. Needleandthreadgrass, which was abundant only on the slope site, was practically eliminated by 10 years of heavy use.

Leaving an average leaf height of 1.2 inches on blue grama at end of each growing season (light utilization) resulted in minor changes in vegetational composition. Utilizing the range to an average of 0.68 inch leaf height of blue grama (heavy utilization) resulted in drastic changes in vegetational composition after 10 years.

Ten years of protection from grazing resulted in a decrease of percentage composition contributed by blue grama and needleandthreadgrass and an increase in western wheatgrass on the slope site. Forbs in the exclosures increased to approximately 25 percent of the total basal cover at the close of this study. They were never abundant in the grazed areas during the 10 years of study.>

Launchbaugh,JL (1967): Vegetation relationships associated with intensity of summer grazing on a clay upland range site in the Kansas 20- to 24-inch precipitation zone. Vol. Technical Bulletin 154. Agricultural Experiment Station, Kansas State University of Agriculture and Applied Science, Manhattan, Kansas.

<Summarizes results of a 20 year study of summer grazing by yearling cattle. Utilization averaged 66, 47.5, and 38.8 percent under heavy, moderate, and light grazing, respectively, during the last 10 years of the experiment.

Total herbage production was greatest under light grazing and differences among all treatments were significant. Composition of herbage yield was associated with stocking rate. Buffalograss production was greatest under heavy grazing and lowest under light grazing. Blue grama and western wheatgrass both produced most under light grazing and least under heavy grazing.>

Laycock,WA (1967): How heavy grazing and protection affect sagebrush-grass ranges. J. Range Management 29, 206-213.

<The author found that heavy late-fall sheep grazing following spring deferment improved deteriorated sagebrush-grass range by reducing sagebrush and increasing the production of grasses and forbs.>

<< It is important to note that the sagebrush on the range studied is three-tip sagebrush (*Artemisia tripartita*) and not the much more common big sagebrush. Three-tip sagebrush is much more palatable than big sagebrush; the results of this study should not, therefore, be extrapolated to big sagebrush-grass ranges.>>

Laycock,WA; Conrad,PW (1981): Responses of vegetation and cattle to various systems of grazing on seeded and native mountain rangelands in eastern Utah. J. Range Management 34, 52-58.

<This study compared several grazing systems in an allotment on the Ashely National Forest in Utah. On the native sagebrush-grass range, which was in fair to good condition and grazed at a moderate intensity, rest-rotation was not a better system than summer-long grazing. Utilization during this study was less than 40%.>

Lewis,JK; Van Dyne,GM; Allsee,LR; Whetzal,RW (1956): Intensity of grazing. South Dakota Agricultural Experiment Station Bulletin 459. Brookings, South Dakota.

<Studied grazing on western South Dakota range from 1942-1955 and concluded that "a utilization of the annual forage production of between 30 and 45 percent from May 1 to December 1 would result in maximum sustained livestock production consistent with maintaining the soil and vegetative resources.">

Martin,SC; Cable,DR (1964): Managing semidesert grass-shrub ranges: Vegetation responses to precipitation, grazing, soil texture, and mesquite control. U.S. Department of Agriculture, Forest Service Technical Bulletin No. 1480.

<Reports on a 10-year study on the Santa Rita Experimental Range near Tucson, Arizona. Mean annual precipitation is 13 inches. Distances up to 1 mile from water did not greatly reduce utilization by cattle on the relatively level, rock-free study area. Utilization 1/4 mile from water averaged 48 percent compared to 44 and 43 percent at 5/8 and 1 mile, respectively. Perennial grass intercept and herbage production held up best where utilization was lightest. Average utilization substantially greater than 40 percent was consistently detrimental to perennial grasses>

Martin,SC; Severson,KE (1988): Vegetation response to the Santa Rita grazing system. J. Range Management 41, 291-295.

<Changes in vegetation under yearlong grazing were compared with those under the Santa Rita grazing system, a rotation system designed for southwestern U.S. rangelands where 90% of the forage is produced in mid- to late-summer. The sutdy was conducted on the Santa Rita Experimental Range near Tucson, Arizona, from 1972 to 1984. In 1984 there were no differences ($P<0.05$) in grass densities, forb densities, shrub densities, or shrub cover on pastures grazed yearlong or in the Santa Rita rotation. Lack of response to grazing schedules is attributed to initial plant densities near the maximum the sites could support and to moderate grazing during the study period.

Average herbage yields of pastures were not related significantly to grazing treatments but correlated strongly ($r=0.909$) with long-time summer rainfall means. Results support the observation that rotation grazing may not improve ranges that are in good condition. It is concluded, however, that the Santa Rita Grazing System may accelerate recovery of ranges in poor condition.

Planned rates of stocking were the average numbers estimated to be necessary to utilize 40% of the perennial grass produced in the study pastures from 1959 through 1968.>

McCormick,JC; Galt,HD (1993): Forty years of vegetation trend in southwestern New Mexico. In: Vegetation Management of Hot Desert Rangeland Ecosystems, a symposium, pp. 68-79.

<Range trend determinations were made for 46 range sites distributed over a 6-county region of southwestern New Mexico. Significant improvement occurred between 1952 and 1992 on 41 sites, no change was noted on 1 site, and trend declined on 3 sites. Good condition occurred on 49% of the sites in 1992 compared to 29% of the sites in 1952. The average of all transects shows perennial plant cover increased from 14% in 1952 to 35% in 1992. Bare ground decreased from 72% in 1952 to 24% in 1992.

The greatest change in improvement of vegetation occurred during the last decade of the study. In this period, a significant improvement in vegetation and a steady decline int he percent of bare ground occurred. Reasons for these changes are: (1) almost a two-fold increase in water developments from 1961 to 1990; (2) more conservative stocking rates; (3) improved livestock distribution from fencing; and (4) above average precipitation during the last 10 years of the study.>

McKinney,E (1997): It may be utilization, but is it management? Rangelands 19, 4-7.

<Notes the problems associated with the measurement of utilization. Average utilization along transects tells us nothing about impacts to the individual plants. For example an average utilization of 51% would result from a transect with 6 plants heavy (6*70%=420), 1 plant moderate (1*50%=50), 1 plant light (1*30%=30), 1 plant slight (1*10%=10), and 1 plant unused (1*0%=0). The conclusion would be that the area was grazed at a moderate level, even though only one plant was actually grazed at this level.

Maintains that overgrazing does not occur after the grazing animal makes one visit to the plant; it occurs after a revisit to the plant before it has had a chance to regrow. He gives another example of a transect on which 4 plants were grazed to the severe level, 2 plants heavy, and 4 plants ungrazed, which results in an average of moderate, even though 40% of the plants are severely grazed.>

<<The problems the author notes with respect to averaging utilization values can be overcome either by using the *median* rather than the mean (in which case both of his examples would come out to be heavy utilization) or by taking into account the percentage of the total number of plants of the key species that have any level of grazing (see Holechek 1993; Valentine 1970).>>

Miller,RF; Donart,GB (1979): Response of Bouteloua eriopoda (Torr.) Torr. and Sporobolus flexuosus (Thurb.) Rydb. to season of defoliation. J. Range Management 32, 63-67.

<Authors looked at the effects of defoliation by clipping in different seasons on black grama (*Bouteloua eriopoda*) and mesa dropseed (*Sporobolus flexuosus*) on the New Mexico College Ranch near Las Cruces. Black grama plants clipped during or after flowering, or continuously through the growing season, produced less herbage in the following year than those plants clipped during the vegetative state. Removal of 65% of the current year's growth any time during the growing season significantly reduced stolon numbers on black grama. Mesa dropseed clipped during maturity, during flowering, or clipped continuously throughout the growing season was negatively affected on one or more of the plant parameters measured. Clipping during the vegetative state had little apparent effect on plant vigor. Both species were unable to tolerate continuous clipping at 65% herbage removal.>

Miller,RF; Donart,GB (1981): Response of Muhlenbergia porteri Scribn. to season of defoliation. J. Range Management 34, 91-94.

<Removing 65% of the leaf area of bush muhly (*Muhlenbergia porteri*) in three consecutive years during the growing season reduced plant vigor regardless of the season of clipping. Late or continuous season defoliation had the greatest impact on food reserves, production, crown diameter and number of stem internodes. Defoliation during the vegetative stage had the least effect of the clipping treatments, but this is likely because only 30% of the total season's growth was removed under this treatment. The authors conclude that to maintain stands of bush muhly, utilization must be below 65%, especially if grazing is occurring after flowering.>

Mueggler,WF (1975): Rate and pattern of vigor recovery in Idaho fescue and bluebunch wheatgrass. J. Range Management 28, 198-204.

<The rate and pattern of vigor recovery of protected individual Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Agropyron spicatum*) were studied for 5 years after heavy and extreme clipping. The removal from heavy clipping approximated 50% removal of the total herbage weight. Bluebunch wheatgrass was not only more sensitive to clipping, but recovered more slowly than Idaho fescue. Idaho fescue of moderately low vigor required approximately 3 years and bluebunch wheatgrass a projected 6 years to approach normal vigor. Recovery from very low vigor may take more than 6 years of protection for Idaho fescue and 8 years for bluebunch wheatgrass.

Maximum leaf length can be used as a reliable index of Idaho fescue vigor. Flower stalk numbers combined with maximum lengths indicate vigor in bluebunch wheatgrass.>

<<Paper shows that you can't count on grazing systems with one or even two years rest to compensate for overutilization of these two key species.>>

Paulsen,HA,Jr; Ares,FN (1962): Grazing values and management of black grama and tobosa grasslands and associated shrub ranges of the Southwest. U.S. Department of Agriculture, Forest Service Technical Bulletin No. 1270. Fort Collins, Colorado.

<Summarizes research conducted on the Journada Experimental Range from 1916-1953. Conservative grazing removes up to 40 percent of the herbage; intermediate use removes between 40 and 55 percent of the herbage; heavy grazing removes more than 55 percent. Recovery of black grama was greatest on quadrats conservatively grazed>

Pearson,HA (1973): Calculating grazing intensity for maximum profit on ponderosa pine range in northern Arizona. J. Range Management 26, 277-278.

<Reports on a study from 1963-1967 in a ponderosa pine range near Flagstaff, Arizona. Concluded that the range producing 500 lbs forage per acre is grazed most economically at 30% utilization and range producing 1000 lbs forage per acre is grazed most economically at 38% utilization. Both of these grazing intensities on Arizona fescue-mountain muhly range would be considered moderate and would not adversely affect long-term forage production.>

Pechanec,JF; Stewart,G (1949): Grazing spring-fall sheep ranges of southern Idaho. U.S. Department of Agriculture Circular No. 808. Washington, D.C.

<The authors found that the best management strategy on sagebrush-grass rangelands is conservative stocking. They note: "By fall the [perennial grass] plants are mature and less susceptible to injury than in spring. They can stand heavier use. *Even so, fall grazing must be conservative*. [Emphasis added.] The herbage left after spring grazing provides for the production of plant foods needed to maintain vigor, produce seed, and support early growth the following spring. The herbage left in the fall protects the root crown of herbaceous species against cold during the winter.

The authors note that sheep operators cannot vary livestock numbers rapidly and widely enough to meet the extreme fluctuations in herbage and forage production and that the best recourse is to maintain a nearly constant rate of stocking that is low enough to provide adequate forage in all but extreme drought years. With this level of stocking about 50 to 60% of the herbage of finer grasses will be left after spring grazing, and 30 to 40% will be ungrazed at the

end of the fall season. Only about 40-50% of the herbage of wheatgrasses will be utilized at the end of fall.>

<<Note the need for conservative utilization even in the "dormant" season, in order to leave residue that will protect the root crowns of perennial grasses from freezing. The authors recommend conservative utilization levels at all times of year.

Peck,C (1994): Carrying capacity on arid rangelands. Western Beef Producer, 1 and 6.

<Summarizes views of Jerry Holechek on stocking rates. Heavy stocking rapidly decreases the forage production capability of ranges in desert areas. "One of the cheapest ways to increase forage production on most ranges is to reduce stocking rate." "On a Chihuahuan desert range in New Mexico, for example, forage production increased from 160 pounds per acre to over 600 pounds during a 25-year period under conservative stocking (30% use of key forages)." "Grazing studies in the more humid central Great Plains concluded most of the improvement in forage production from light grazing occurs during the first five to seven years. However, on desert ranges the benefits of conservative stocking tend to accumulate and are greatest after a 5- to 10-year period." "In arid shrubland ranges of the Southwest, light grazing can be a useful means of improving forage production during the early stages of range deterioration if desirable forages are still present but in low vigor. However, light grazing has shown low potential for recovery of highly deteriorated, brush-infested ranges.">

<<Note: this summarizes part of the 1993 Holechek paper, "Managing stocking rates to achieve range resource goals.">>

Peck,C (1994): Stocking rate strategies and the economy. Western Beef Producer, 7.

<"In arid areas, flexible stocking has minor advantages over constant stocking at a conservative rate. This is because forage crops vary more between years due to erratic rainfall, carry-over residue plays a bigger role in meeting livestock nutritional needs, and there is greater risk of long term damage to the range if maximum stocking and drought coincide.">

Peck,C (1994): Residue important in stocking rate decisions. Western Beef Producer.

<<Most stocking rate studies have used percent utilization of forage species to measure grazing intensity. But standing crop measurements are more useful for making management decisions according to Holechek. "Holechek noted that heavy stocking causes desirable wildlife species such as pronghorn, prairie chickens and wild turkeys to decline or disappear since inadequate vegetation is available to meet their cover and food needs."

Low residue makes the soil more vulnerable to wind and water erosion. "Many ranchers and range professionals held the belief residue was unimportant to forage plants after completion of growth." Research, however, has shown residue during dormancy is critical in protecting plants from extreme temperatures and destruction of the growing points in the crown, from insects, rodents, and pathogens. "Heavy defoliation during dormancy cuts production almost as much as during active growth."

Note: this summarizes parts of the 1993 Holechek paper, "Managing stocking rates to achieve range resource goals.">>

Peck,C (?): Range "standards" and "guidelines" not the same. Western Beef Producer, 12.

<Summarizes concerns of Dr. William Laycock with utilization and stubble height guidelines. While these may be appropriate for broad guidelines, Laycock says they're inappropriate as standards to be applied by agencies. Responding to Holechek's stubble height guidelines for key species (12-14 inches for tall grasses, 6 to 8 inches for mid grasses, and 2 to 3 inches for short grasses) Haycock says "even as a guideline the mid-grass height is not appropriate for drier sites. Leaves of mid grasses very often do not grow 6 to 8 inches high. Only the flowering stalk, which contains little of the weight, may reach this height. Thus a National Forest or BLM district picking up these heights as 'standards' would limit use of mid grasses to only 10 or 15% of their weight." According to Laycock, "management" includes water and salt distribution, riding, etc., and focusing too much on stocking rate leads to inappropriate utilization limits, complicated formulas to predict utilization, and all of the other things that are not managing the range but "policing" the range.>

Pickford,GD; Reid,EH (1948): Forage utilization on summer cattle ranges in eastern Oregon. U.S. Department of Agriculture Circular No. 796. Washington, D.C.

<Authors caution that attention must be paid to the utilization of the key forage species. While only 23 percent of the total herbage in the study area was grazed by the end of the grazing season, important forage grasses like bluebunch wheatgrass and prairie junegrass were utilized 60% and 55%, respectively, levels that are "as fully as considered safe.">

Pieper,RD; Heitschmidt,RK (1988): Is short-duration grazing the answer? Journal of Soil and Water Conservation 43, 133-137.

<The authors summarize literature on impacts of livestock grazing, grazing systems in general, and short duration grazing in particular. They find the claims for "hoof actions" benefits to be untrue and that impacts from grazing animals to be the same under short duration grazing as under other grazing systems. Monitoring grazing intensity is critical whether rangelands are under grazing systems or not.

The authors state: "What is the surest way to halt range deterioration and enhance conservation of this valuable resource? Disregarding any economic considerations, destocking is the quickest, surest, and most viable way to reduce current deterioration trends wherever they are occurring."

They further state: "Neither of us are advocating total and continued rest: that is unnatural as well. Instead, we are suggesting that stocking rate is and always will be the major factor affecting the degradation of rangeland resources. No grazing system can counteract the negative impacts of overstocking on a long-term basis.">

Platts,WS (1981): Influence of forest and rangeland management on anadromous fish habitat in Western North America. 7. Effects of Livestock Grazing. Pacific Northwest Forest and Range Experiment Station Forest Service, U.S. Department of Agriculture, Portland, Oregon. 25 pages.

<Summarizes effects of livestock grazing on anadromous fish habitat. Rates various grazing strategies as to the condition of riparian-aquatic habitat: 1) year-long grazing: poor; 2) season-

long grazing: poor; 3) deferred grazing: poor to fair; 4) rotation grazing: poor to fair; 5) deferred-rotation grazing: poor to fair; 6) rest-rotation grazing: poor to variable; 7) short duration, high intensity grazing: variable; 8) no grazing: good to excellent. Notes that with 6) and 7), resource damage, especially streambank cutting, within heavy-use units may not be repaired within the grazing cycle.

Recognizes 3 goals related to fisheries: 1) sufficient streamside vegetative canopy should be maintained to prevent unacceptable water temperatures; 2) streambanks should be well vegetated to hold soil in place and to keep trampling damage by livestock to a minimum; and 3) overhanging streamside vegetation (within 2 feet of stream surface) should be maintained to provide needed fish cover.

Recommends the following range management practices to protect, restore, or enhance fish and riparian habitats: 1) allow complete rest from livestock grazing to degraded riparian areas for as long as required to meet the above three goals; 2) defer grazing on streamside areas to late fall when possible; 3) recognize specific needs of the different ecological units in pastures (must manage hillsides and riparian areas as separate units); 4) improve off-stream distribution of livestock in areas bordering riparian zones; and 5) allocate vegetative cover in the streamside zone for fish at the same time forage is allocated for livestock grazing.>

Platts,WS (1981): Sheep and cattle grazing strategies on riparian-stream environments. Proceedings of the Wildlife-Livestock Relationships Symposium, 20-22 April 1981, Moscow, Idaho. 19 pp.

<Research studies involving the effects of cattle and sheep grazing strategies on stream riparian habitat are discussed. Initial results indicate that herded sheep grazing may have little effect on streams and the riparian environment. The effects of cattle grazing first appear on the streambanks and riparian vegetation. Habitat alteration occurs at utilization rates of 65% or more, and alteration is insignificant when utilization is less than 25 percent. Continued research is needed to identify grazing strategies compatible with riparian environments and to develop new grazing strategies.>

Platts,WS (1984): Progress in range riparian-stream research at the intermountain forest and range experiment station. Proceedings of the Bonneville Chapter of the American Fisheries Society, Feb. 8-9, 1984. Logan, Utah. 78-84.

<Eight options are available for land managers to use in managing range riparian-stream habitats. These options vary from the elimination of grazing until recovery occurs to complicated grazing strategies. Options with the best opportunity for maintaining and improving riparian-stream habitats are the inclusion of the riparian pasture, fencing streamside corridors, changing the kind of livestock, and adding more rest to the grazing cycle.>

Platts,WS (1985): Compatibility of livestock grazing strategies with riparian-stream systems. Proceedings: Range watersheds, riparian zones and economics. Corvallis, OR, Oregon State University, 1985. Pages 67-74.

<No commonly used grazing strategy works in all situations. The most promising grazing strategies for maintaining or rehabilitating riparian-stream systems are those that include one of the following options: (1) inclusion of the riparian pasture as a separately managed resource; (2) fencing streamside corridors; (3) changing the kind of livestock (from sheep to cattle in some

situations; (4) adding more rest to the grazing cycle; (5) reducing intensity of streamside forage use; (6) changing the timing of forage use.

Platts' studies tend to support the statement of Holechek (1983) that the benefits from rest in a rest-rotation grazing strategy may be nullified by the extra use that occurs on the grazed pastures when use of the riparian forage is heavy. A three-pasture rest-rotation strategy can, however, leave a vegetative mat on the streambank in 2 out of every 3 years, 1 year during early grazing and the other during the rested year.>

Platts,WS; Nelson,RL (1985): Streamside and upland vegetation use by cattle. Journal of Rangelands 7(4), 05-07.

<Eight years of utilization data were collected from 9 study areas in Idaho, Utah, and Nevada. Cattle preference for streamside areas and their associated vegetation led to consistently greater use of vegetation on these sites. While the estimates of overall pasture use were within the upper end of the moderate range (26%-50%) or the lower end of the heavy range (51-75%), streamside vegetation was more frequently in the very heavy use range (76%-100%). None of the grazing systems employed at the study sites was successful in promoting a balance between upland and riparian grazing use. Range management decisions based on overall pasture use may result in inappropriate watershed management decisions. Riparian areas should be monitored and managed separately.>

Potter,LD; Krenetzky,JC (1967): Plant succession with release from grazing on New Mexico rangelands. J. Range Management 20, 145-151.

<After 25 years of protection from grazing, grassland plots tripled in percent of ground cover of grasses. Grazed desert grasslands showed continued increases in mesquite. Protection resulted in remarkable increases in grass cover in ponderosa pine and aspen types.>

Ralphs,MH; Kothmann,MM; Taylor,CA (1990): Vegetation response to increased stocking rates in short-duration grazing. J. Range Manage. 43, 104-108.

<Short-duration grazing (SDG) has been purported to increase forage production and utilization compared to other systems, and thus can sustain higher stocking rates. This study was designed to determine if standing crop could be maintained as stocking rates increased. Four stocking rate treatments ranging from the recommended rate for moderate continuous grazing to 2.5 times the recommended rate were applied in a simulated 8-pasture SDG system. There was little change in frequency and composition of short-grasses over the study, but mid-grass frequency and composition both declined. Standing crop of all major forage classes declined as stocking rates increased. However, the rate of decline was less than proportional to the increase in stocking rate during the growing season. By fall, standing crop was inversely proportional to stocking rate, leading us to conclude that standing crop could not be maintained at the higher stocking rates. Low standing crop in the fall indicated a potential shortage of forage at the high stocking rates during the winter.

Forage responses to increasing stocking rates observed in this study under SDG are similar to those expected from continuous grazing at the same stocking rates.>

Ratliff,RD; George,MR; McDougald,NK (1987): Managing livestock grazing on meadows of California's Sierra Nevada. Cooperative Extension, University of California, Division of Agriculture and Natural Resources, Berkeley, CA. 9 pages.

<A table gives estimated wet meadow productivity, minimum amounts of residual herbage, and grazing capacity by condition class and elevation. Residual herbage is based on leaving 65 percent of average annual production for meadows in excellent condition, 70 percent for good condition, 75 percent for fair condition, and 80 percent for poor condition. Notes that residual herbage is a reliable first indicator of proper grazing management, but that range condition and trend analysis is still necessary to determine if meadow condition is improving.

Recommends measuring residual herbage using either the harvest, ocular estimate, or double sampling methods. Notes that stubble heights and ungrazed height-weight relationships can be used to indicate when herbage use is proper. Also notes that stubble heights can be used to estimate residual herbage, but that these should be related to weight per unit area and the relationships developed for specific kinds of meadow sites.>

Sauer,RH (1978): Effect of removal of standing dead material on growth of Agropyron spicatum. J. Range Management 31, 121-122.

<Standing dead material was clipped from clumps of bluebunch wheatgrass (*Agropyron spicatum*), with no other disturbance. Clumps without dead material, compared to those with, had less green material and shorter leaves but did not differ in height or number of flowering culms or head lengths. Standing dead appears to be beneficial to bluebunch wheatgrass.>

<<Another paper indicating that attention must be given to proper utilization levels even in the "dormant" season.>>

Sharp,L; Sanders,K; Rimbey,N (1994): Management decisions based on utilization--is it really management? Rangelands 16, 38-40.

<The authors do not believe that using utilization data is an appropriate management tool. The authors cite difficulties in measuring utilization, variability of utilization levels on bluebunch wheatgrass from 69% to 38% and on crested wheatgrass of 29% to 89% with no apparent harm to the range, and the difficulties in setting proper use levels.

Instead of time consuming utilization measurements, the authors recommend taking photographs of the range at various times during the year; these can be used to evaluate both utilization and range trend. They recommend supplementing the photographs with weather data, actual use records, and field notes on insect, rodent, and wildlife activity.>

<<Because crested wheatgrass is much more resistant to grazing than most native range grasses, data on its ability to cope with high utilization levels cannot be extrapolated to native grasses. They cite articles by Caldwell (1984) and Menke (1987) as evidence of the difficulty in setting proper use levels. These papers, however, especially Menke's, were responding to then recent attempts, primarily BLM's through the SVIM process, to determine carrying capacities on rangelands by assigning proper use factors to a host of different plant species occurring on the same range site. As currently employed, utilization levels are set for individual key species (often just one at any key area, but sometimes two or three), not for all of the plants simultaneously.

The criticisms of Caldwell and Menke are therefore not applicable to utilization guidelines being applied by land management agencies in 1997.>>

Shoop,MC; McIlvain,EH (1971): Why some cattlemen overgraze–and some don't. J. Range Management 24, 252-257.

<Cattle can make high gains on overgrazed range for a few years--if they are fed enough hay, grain, or protein. The supplements mask the low and declining production of overgrazed range. This combination of overgrazing and extra supplements can be profitable until the plant and soil resources are badly damaged, or until a series of drouth years combined with low or dropping cattle prices "terminate" the business or put it on a subsistence level.

Over the long term, moderate grazing is more profitable than overgrazing, and in the short term, is much more stable financially.>

Skovlin,J (1987): Southern Africa's experience with intensive short duration grazing. Rangelands 9, 162-167.

<"...evidence in literature from Zimbabwe and elsewhere in southern Africa indicates that it is impossible to have both heavy stocking and improvement in range condition. In fact, studies of SDG involving 12-16 units at only medium rates of stocking have shown no greater improvement than conventional systems." "The assumption that stocking rate or level of vegetative use is unimportant if an appropriate rotational system is employed is flawed." "Emphasis on SDG from southern Africa is now away from high stocking rates to accomplish non-selective grazing with preference toward higher animal performance." Note: SDG=short duration grazing.>

Skovlin,JM; Harris,RW; Strickler,GS; Garrison,GA (1976): Effects of cattle grazing methods on ponderosa pine-bunchgrass range in the Pacific Northwest. (U.S. Department of Agriculture, Forest Service Technical Bulletin No. 1531)

<Heavy stocking lowered grazing capacity, depleted ground cover, reduced cattle gains, and limited game use. Moderate stocking maintained grazing capacity, provided acceptable cattle gains, and slightly lowered the amount of high quality forage. Light stocking provided a substantial increase in capacity and the best cattle gains per head but not per acre; it permitted the highest game density under dual use. Protection from cattle use slightly improved the composition of high quality forage species, produced little change in potential grazing capacity, furnished no marketable product, but provided the greatest game use.

Average utilization varied by species. Two examples from the grassland site follow. Bluebunch wheatgrass: light use was 34% under both season-long and deferred rotation; moderate use was 49% and 41% under season-long and deferred rotation, respectively, and heavy use was 55% and 50% under season-long and deferred rotation, respectively. Sandberg bluegrass was 7% and 8% (light), 16% and 11% (moderate), and 21% and 17% (heavy) under season-long and deferred rotation, respectively.>

Smith,DA; Schmutz,EM (1975): Vegetative changes on protected versus grazed desert grassland ranges in Arizona. J. Range Management 28, 453-458.

<The authors studied protected and grazed rangelands in southeastern Arizona. They classed the grazed range in a low stage of range condition and the protected range in an intermediate stage. They concluded that without a change in treatment and management, mesquite would continue to increase on both ranges.>

Smith,DR (1967): Effects of cattle grazing on a ponderosa pine-bunchgrass range in Colorado. U.S. Department of Agriculture, Forest Service, Technical Bulletin 1371. Washington, D.C.

<Reports on the continued results of Johnson's (1953) study. Johnson (1953) reported results for 1942-1947 and part of 1950. This bulletin presents data for 1940-1959 and uses these results in a reevaluation of the earlier findings of Johnson (1953). The following summary is given: “Overall, best results were obtained by utilizing 30 to 40 percent of the dominant bunchgrass herbage by the end of the season on ponderosa pine-bunchgrass range. This intensity of grazing is recommended. While these results apply specifically to the combination of soil, vegetation, and topographic situations evaluated at Manitou, the general principles developed and conclusions drawn confirm those of other workers on widely different range types in western North America.”>

Smoliak,S (1974): Range vegetation and sheep production at three stocking rates on Stipa-Bouteloua prairie. J. Range Management 27, 23-26.

<The author reports on a study from 1951-1969 on *Stipa comata-Bouteloua gracilis* prairie at the Agriculture Canada Research Substation in Alberta. Three levels of grazing, heavy, moderate, and light, were applied to the range, which was grazed for 9 months each year. Range deterioration and poor livestock performance resulted from heavy grazing. The author concluded that this range should be stocked at not less than 1.0 acre per ewe per month to maintain the vegetative cover in a productive condition. This corresponds to a moderate rate of utilization (average of 53% over the 18-year period.>

Sneva,FA (1980): Crown temperature of Whitmar wheatgrass as influenced by standing dead material. J. Range Management 33, 314-315.

<The impact of standing dead material on the crown temperature, yield, and crude protein concentration of Whitmar wheatgrass (*Agropyron inerme*) was studied. During the day standing dead material significantly lowered temperature in the crown but influenced temperatures during the night only slightly. Herbage yield of new growth was greater and its crude protein concentration lower on plots with than without standing dead material.>

<<Another paper showing the importance of standing dead material to plant vigor. Implications are that attention must be paid to proper utilization even in the "dormant" season.>>

Taylor,CA,Jr; Ralphs,MH; Kothmann,MM (1997): Technical note: Vegetation response to increasing stocking rate under rotational stocking. J. Range Management 50, 439-442.

<The authors report on a 10-year study on the Texas Agricultural Experiment Stations near Sonora, Texas. The objective was to evaluate vegetation response to increasing stocking rates under rotational stocking (3 days graze, 51 days rest) and long-term rest. The 4 stocking rate treatments ranged from the recommended rate for moderate continuous grazing to 2.7 times the recommended rate. Common curly-mesquite (*Hilaria belangeri*) increased in all grazed treatments

and decreased in the livestock exclosure. Sideoats grama (*Bouteloua curtipendula*) along with other midgrasses decreased in all grazed treatments and increased in the livestock exclosure.

Because the midgrasses were palatable species and not abundant, they were defoliated too intensively and too frequently. Rotational stocking was not able to sustain initial species composition at any of the stocking rates tested.

Even though rotational stocking methods have been claimed to improve or maintain range condition, range managers must be alert when implementing rotational stocking on semi-arid rangelands. Increasing the density and production of preferred plants is a difficult and slow process. The presence of competing vegetation and the influence of precipitation, soil type, and intensity and frequency of grazing results in variable responses to stocking methods.

For rotational stocking to be successful, we recommend monitoring of grazing use on preferred plants. Range managers must then adjust both grazing methods and animal numbers to maintain proper use on key forage species. [Emphasis added.]>

<<Must still monitor proper utilization, regardless of whether there is a grazing system in place, and make adjustments as necessary in animal numbers and grazing methods.>>

Thurow,TL; Blackburn,WH; Taylor,CA (1988): Infiltration and interrill erosion responses to selected livestock grazing strategies, Edwards Plateau, Texas. J. Range Management 41, 296-302.

<The authors examined the effects of 4 types of grazing on infiltration rate and interrill erosion: moderate continuous grazing (MCG); heavy continuous grazing (HCG); high-intensity, low-frequency grazing (HILF), moderately stocked; and short duration (SDG) and heavily stocked.

The MCG and HILF pastures were able to recover from droughts and maintain initial infiltration rates and interrill erosion. In contrast, infiltration rates decreased and interrill erosion increased on HCG and heavily stocked SDG pastures. The heavy stocking rate and climate rather than grazing strategy were the primary factors influencing the hydrologic responses. Litter was important both to promote infiltration and to protect against rill erosion.>

Trlica,MJ; Buwai,M; Menke,JW (1977): Effects of rest following defoliations on the recovery of several range species. J. Range Management 30, 21-26.

<Seven important forage species were heavily defoliated once to remove 90% of the foliage during each of four different phenological stages. The effects of these defoliations were evaluated in the fall, 2 years after the defoliated plants had received 14 to 26 months of rest. Western wheatgrass, little rabbitbrush, and scarlet globemallow made good recovery after a single defoliation followed by 14 to 26 months of rest. A 14 to 26 month rest period was insufficient for complete recovery of antelope bitterbrush and fourwing saltbush. The rest period was insufficient for recovery of herbage yield of blue grama, except when the defoliation was made during the quiescence phenological stage. The rest period was also insufficient for recovery of fringed sagewort; the 90% defoliation was extremely severe for this species and several years of nonuse would be required for its recovery.

The authors also looked at the effects of 3 and 6 heavy defoliations to these species. See paper for results.>

<<This paper provides evidence that a single year's rest is likely insufficient to provide for recovery of many forage plant species.>>

Troxel,TR; White,LD (1989): Balancing forage demand with forage supply. Texas Agricultural Extension Service Publication B-1606. Texas A&M University. College Station, Texas.

<Range research has determined that on a year-long average properly stocked livestock harvest only 25%of the forage produced, commonly referred to as a harvest efficiency of 25 percent. This means that 25 percent of the forage is consumed by livestock, 25 percent is lost to natural disappearance and 50 percent must remain in the pasture for soil protection and future forage production.>

Valentine,KA (1970): Influence of grazing intensity on improvement of deteriorated black grama range. New Mexico Agricultural Experiment Station Bulletin 553. Las Cruces, New Mexico.

<Reports on an experiment conducted on the New Mexico Agricultural Experiment Station Ranch from 1953-1964. Although the percentage of weight of current herbage grazed, a measure of utilization, is often used among professional range managers, it is more direct and often more meaningful for management purposes to recognize levels of use in terms of stubble height and seedstalks remaining after grazing. These characteristics have to do directly with maintenance and reproduction of the plants and protection of soil. These can be evaluated effectively in a qualitative (visual) manner.

Light and moderate use of black grama plants 18 to 20 inches high results when stubble heights are about 5-6 inches and 3-4 inches, respectively. Under light and moderate levels of use on the range, where large numbers of the plants are present, cattle do not use the plants to uniform stubble height. Instead, light and moderate use involves full, or nearly full, proper use of the plants which are grazed and light or no use of the remaining plants. Thus, light use would result from grazing about one-third of the plants in a stand to full, proper use and leaving the remaining two-third ungrazed. Moderate use would result from grazing about two-thirds of the plants and leaving one-third ungrazed.

Plant vigor was significantly greater under light and moderate use than under "proper" and heavy use. Under light and moderate use, an average of 38 percent of the cover and 45 percent of the yield of black grama on good-condition range was attained; under proper and heavy use, the average were only 26 percent of the cover and 22 percent of the yield of black grama on good-condition range.>

Vallentine,JF (1990): Grazing management. Academic Press, Inc., New York.

<Gives percent utilization guidelines (which he calls "suggested proper use factors") adapted from Holechek (1988). Suggested proper use factors are 25-35% for southern desert shrublands; 30-40% for northern desert shrublands, semidesert grass and shrublands, sagebrush-grasslands, and oak woodland and chaparral; 35-45% for western mountain grasslands, shrublands, and coniferous forest; and 50-60% for California annual grassland (only those relevant to California are included in this summary).

He also gives categories for utilization (slight=1-20%; moderate=21-40%; full=41-60%; close=61-80%; severe=81-100%) and discusses the use of residue in lieu of utilization. Summarizes Holechek's (1988) findings with respect to residue: 300 pound/acre satisfactory on Colorado short-grass range, 160 pound/acre grass residue on Oregon big sagebrush-grass ranges, and 250-1,100 pound/acre in California annual grassland type, depending on the site.>

Van Poollen,HW; Lacey,JR (1979): Herbage responses to grazing systems and stocking intensities. J. Range Management 32, 250-253.

<The authors reviewed data from studies previously conducted throughout the West and looked at the increase in herbage production as a result of implementation of grazing systems and of reductions in stocking rate. Utilization levels were defined as follows: Heavy=60-80%; Moderate=40-60%; light=20-40%. They found that mean annual herbage production increased by 13% when grazing systems were implemented at a moderate stocking rate. Increases were larger (35% and 27%) when continuous livestock use was reduced from heavy to moderate, and moderate to light, respectively. This suggests that land managers should place more emphasis on proper stocking intensity and less on grazing system implementation.>

<<Stocking rates (and utilization levels) are more important that grazing systems in increasing herbage production.>>

Wolfshohl,K (1996): More beef with less stress. Grass Roots September-October, 2 and 8.

<Summarizes experience of Spade Ranches in arid West Texas and eastern New Mexico, which produces twice as much beef on some of its divisions as it grew 20 years ago. Each ranch uses a 4-pasture rest-rotation grazing system, but pays special attention to stocking rate. During drought "the secret is not to wait too long to decrease the stock and not to be overstocked anytime. We watch our forage and never go by the condition of our animals. If you do, you've waited too long.">

Woolfolk,EJ (1949): Stocking northern Great Plains sheep range for sustained high production. U.S. Department of Agriculture Circular 904. Washington, D.C.

<Conservative stocking is recommended. Not more than 29% of the herbage of blue grama should be removed by grazing on a properly stocked sheep range. Such use results from grazing 45% of the total number of individual plants to an average stubble of 0.6 inches (notes that Costello 1942 recommends a 1.5 inche stubble for blue grama on properly grazed cattle ranges in Colorado, where this species grows taller, is more abundant, and composes a greater percentage of the vegetative composition than in the northern Great Plains).

Bluestem should be not be grazed to an average stubble shorter than 2.5 inches and not more than 35% of the plants should be grazed for proper use on northern Great Plains sheep range. Such use removes about 20% of the herbage produced.

For threadleaf sedge, grazed stubbles should average about 0.8 inches. The percentage of individual plants grazed should not exceed 33 to 35%. This degree of grazing removes 19 to 20% of the herbage.>

Yorks,TP; West,NE; Capels,KM (1992): Vegetation differences in desert shrublands of western Utah's Pine Valley between 1933 and 1989. J. Range Management 45, 569-578.

<In 1989 the authors repeated (with some modifications) a transect first conducted in 1933 in southern Pine Valley, Utah. Vegetation included a low rabbitbrush type, a spiny hopsage type, and a sagebrush type. Each segment of the transect includes a mixed understory of grasses and forbs.

Changes in rangeland vegetation integrate the consequences of livestock grazing intensity and possible climatic change, as well as other factors. This study showed substantially greater understory cover as a relative proportion of total plant cover occurred in 1989 in all vegetation types examined. Both overall cover and relative cover of perennial grasses increased greatly between 1933 and 1989. While the total number of species is more or less unchanged, more of the species in all three vegetation types are playing an appreciable role.

The changes are attributable to reductions in grazing pressure, both numbers and season of use. The authors state "Such an increase in perennial grasses is encouraging in the Pine Valley area, where desertification was reported to have been an obvious process....This change is especially notable because it occurred on land that received no substantial treatment subsequently, except reduction--not elimination--of domestic grazing pressure. This remains true even if the increase was the partial result of threshold influences of precipitation (Haycock 1991).>

<<This paper shows that improvement can occur from decreases in grazing pressure, even in areas that such improvement wouldn't have been predicted,>>

Yorks,TP; West,NE; Capels,KM (1994): Changes in pinyon-juniper woodlands in western Utah's Pine Valley between 1933-1989. J. Range Management 47, 359-364.

<In 1989 the authors repeated a transect originally run in 1933 through pinyon-juniper communities. They found that significantly greater shrub and perennial grass covers (more than threefold increases) were found in 1989, even where overall dominance is still by pinyon-juniper. Although the total number of species is more or less unchanged, the clear indication from examination of dominance/diversity is that more species are playing an appreciable role, and so could serve as a set of buffers against specialized environmental pressures.

When the increases in perennial grass cover are combined with increases in understory forbs, "the differences which were observed in Pine Valley can only be held as strong evidence that in at least one publicly owned area, improvement in condition has indeed occurred, and that this is concurrent with changes in livestock management (i.e., reductions in pressure in both length of seasons of use and in absolute numbers of animals, but not in their elimination) which followed the Taylor Grazing Act of 1934.">

<<This paper shows that improvement can occur from decreases in grazing pressure, even in areas that such improvement wouldn't have been predicted without such practices as chaining or fire.>>