Controlled Grazing Versus Grazing Exclusion Impacts on Rangeland Ecosystems: What We Have Learned

By

Jerry L. Holechek

Keywords: Rangelands, livestock, wildlife, fish, grazing, soils

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Author is professor of range animal ecology, Department of Animal & Range Sciences, New Mexico State University, Las Cruces, NM 88003. This paper was supported by the New Mexico Agricultural Experiment Station and part of project 1-5-27417.

Abstract

This paper provides a review of the impacts on carefully controlled livestock grazing versus grazing exclusion on rangeland ecosystems focusing on arid and semi-arid areas. A total of 18 studies were found that evaluate the effects of controlled grazing versus grazing exclusion on rangeland vegetation. These studies provide evidence that controlled livestock grazing may enhance rangeland vegetation by accelerating plant succession, increasing plant diversity, increasing plant productivity, and reducing plant mortality during drought. These positive impacts of livestock grazing are most likely to occur when grazing intensities are light to conservative. Although over 30 studies are consistent in showing controlled grazing adversely impacts soils through increasing compaction, reducing infiltration and increasing erosion, these impacts generally are of small magnitude and are ameliorated by natural processes that cause soil formation, soil deposition and soil loosening. Plant seedling establishment and mineral cycling can be increased by livestock treading. Some desirable wildlife species can benefit from controlled livestock grazing. Research from the Chihuahuan Desert indicates moderately grazed mid seral rangelands support a higher diversity of wildlife species than those lightly grazed in near climax condition. Rapid riparian habitat improvement has occurred under carefully timed grazing at light to conservative intensities. Controlled grazing impacts on fish populations have not been well studied. In conclusion there is scientific evidence that controlled grazing can play an important role in managing, maintaining and improving rangelands in arid and semiarid regions for a variety of uses and ecosystem services. However more and better designed research is needed on this subject. Claims that managed, information-based livestock grazing is unsustainable in arid and semiarid areas are refuted.

Introduction

Conflict over how public grazing lands in the western United States will be used has become increasingly contentious as the land base in the West has shrunk due to rapid human population increase, urban sprawl and changing social values. Anti-grazing activists are making considerable use of the legal systems and media to further their cause. At the same time public land ranchers have gained staunch supporters and stiffened their resolve. Impacts of controlled livestock grazing on rangeland ecosystems of the western United States have become better understood during the last 20 years as a result of more research and publication of study results. However most of this research is in highly technical peer reviewed journal articles that are generally not read by the public at large. A careful analysis of this research is needed to provide the public, ranchers, lawmakers, government planners, and conservationists with a sound basis for decision making. This review will focus on controlled livestock grazing impacts on ecosystem health with emphasis on vegetation impacts. Soil, watershed, wildlife and fish will be more briefly discussed. Semiarid and arid areas will receive emphasis because livestock grazing is under greatest attack on the public rangelands of the western United States (Donahue 1999).

Primary Sources of Information

All the grazing studies in the western United States will not be exhaustively reviewed. Only those that have involved careful control of intensity, timing and frequency of grazing will be reviewed. However, influential reviews and opinion articles that look at livestock grazing from different perspectives will be identified.

The primary range management textbooks include Stoddart et al. (1975), Valentine (1990), Heady and Child (1994), and Holechek et al. (2001). All these books draw heavily from peer reviewed science and focus on controlled grazing outcomes. These textbooks are essential reading for anyone who wants objective scientific information on controlled grazing. Relevant more specialized textbooks include Branson et al. (1981) on rangeland watershed management, Vavra et al. (eds.) (1994) on grazing impacts on western plant communities, Krausman (ed.) (1996) on rangeland wildlife, and Heitschmidt and Stuth (eds.) (1991) on rangeland ecology.

Another level of books and handbooks is directed more toward the layman or rancher seeking practical information. These include Bell (1973), Savory (1999) and Sayre (2001). Bell (1973) provides an excellent overview of range management based on his experiences as a range conservationist with the USDA – Soil Conservation Service. Sayre (2001) more closely ties his observations, case studies, and viewpoints to peer reviewed studies than Savory (1999).

Noteworthy anti-grazing books include Jacobs (1992) and Donahue (1999). I have found both books to contain some useful information but to be heavily biased and prone to distort many of the facts. Of the two, Donahue (1999) is the most scholarly and convincing (see Batabyal 2000). One of Donahue's most contentious conclusions is that livestock grazing is generally unsustainable on western rangelands receiving less than 30 cm average annual precipitation. I will closely examine this conclusion.

The most comprehensive reviews of scientific information on grazing impacts on rangeland vegetation include Ellison (1960), Milchunas et al. (1988), and Milchunas and Lauenroth (1993). Reviews providing a defense for public land grazing include Holechek (1980) and Holechek (1981). Those that make the case against public land grazing include Fleischner (1994) and Jones (2000). Belsky et al. (1999) reviews various studies showing uncontrolled livestock grazing degrades riparian ecosystems.

Problems with Grazing Exclusion Studies

Fleischner (1994) and Jones (2000) review a wide variety of grazing versus grazing exclusion studies that show livestock grazing has adverse impacts on vegetation diversity, vegetation structure, plant succession, soil stability, nutrient cycling, wildlife diversity, and riparian health. Neither of these reviews that involved over 100 studies takes into account critical details that greatly influence experimental outcomes such as grazing intensity, timing and frequency. What is of particular importance is that Fleischner (1994) fails to consider any of the 35 long term controlled grazing studies identified by Van Poollen and Lacey (1979), Holechek, et al. (1999) and Holechek, et al. (2001) as the foundations of range management. Only one of these foundation studies is mentioned by Jones (2000). Nearly all the studies considered in the Fleischner (1994) and Jones (2000) reviews have serious flaws (Brown and McDonald 1995). These include:

1. inadequate descriptions of grazing treatments or practices,
2. weak study designs, and/or
3. lack of pre-treatment data.

Weak study designs typically include lack of replication in time and space, grazing treatments so poorly described they cannot be reconstructed, non-uniform experimental units, and excessively small experimental units that do not adequately reflect the area studied (Brown and McDonald 1995, Larsen et al. 1998). In the case of grazing versus grazing exclusion studies, very few provide information on grazing intensity, season of use, frequency of use, and use by native herbivores prior to construction. Consequently the reader cannot discern the nature of the grazing impacts that impaired the area.

Controlled Grazing Studies

It has been known for over 100 years that sustained heavy to severe grazing intensities are harmful to soil, vegetation and wildlife. Range scientists and ranchers have long acknowledged the severe grazing that occurred over much of the western United States in the late 1800's and early 1900's was damaging to soil and vegetation. However, it is well established that steady improvement has occurred on both publicly and privately owned rangelands over the past 60 years due to better controlled grazing (Table 1). A quick review of the controlled grazing studies will be provided before consideration of controlled grazing versus grazing exclusion. The basis for this review is Holechek et al. (1999) and Holechek et al. (2001). For more details on the various controlled grazing studies the reader is referred to Van Poollen and Lacey (1979), Lacey and Van Poollen (1981), Milchunas and Lauenroth (1993) and Vavra et al. (eds.) (1994).

What is Sustainable Grazing?

Various stocking rate studies characterize grazing intensity treatments as heavy, moderate and light. Klipple and Bement (1961) define heavy grazing as a degree of forage utilization that does not permit desirable forage species to maintain themselves. Moderate grazing is a degree of herbage utilization that allows the palatable species to maintain themselves but usually does not permit them to improve in herbage producing ability. Light grazing is a degree of herbage utilization that allows palatable species to maximize their herbage producing ability.

The primary measure of grazing intensity used in long term grazing studies has been percent use of palatable forage species. Although it has limitations as a measure of grazing intensity, percent use is more easily understood by ranchers and non-range professionals than other measurements such as stubble heights, percentage of grazed plants, or minimum residues

(Jasmer and Holechek 1984). When several years of data were collected, percent use of forage has been well related to changes in productivity of primary forage plants, livestock performance, and financial returns (Holechek et al. 1999).

When all the stocking rate studies were averaged, Holechek et al. (1999) found heavy grazing averaged 57% use of primary forage species compared to 43% use for moderate and 32% use for light grazing (Table2). Research was remarkably consistent in showing that moderate grazing involved about 45% use of forage (Johnson 1953, Klipple and Costello 1960, Beetle et al. 1961, Paulsen and Ares 1962, Houston and Woodward 1966, Launchbaugh 1967, Martin and Cable 1974, Skovlin et al. 1976, Sims et al. 1976). In some years use approached 60% while in others it was only 20%, but over long time periods an average near 45% maintained vegetation productivity (see also Milchunas and Lauenroth 1993).

Unlike stocking rate studies, research comparing continuous or season-long and rotation grazing systems has shown much inconsistency regarding influences on rangeland vegetation (Van Poollen and Lacey 1979, Holechek et al. 1999, Table 3). Across all studies forage production was 7% higher under rotation compared to continuous grazing. In the semi-arid and desert range types, rotation grazing systems generally showed no advantage over continuous or season-long grazing. However in the more humid range types, forage production averaged 20-30% higher under rotation grazing. Generally rotation grazing has been more beneficial than continuous grazing to desirable forage species in the humid types. However in flat semiarid and arid areas, rotation has shown no definite advantage. In mountainous areas rotation grazing systems give high value, easier access areas (riparian zones) opportunity for recovery, and can be advantageous over season-long grazing. More detailed discussions of the results from various grazing system studies are provided by Vallentine (1990), Heady and Child (1994) and Holechek et al. (2001).

One point made by leading rangemen should be emphasized. Stocking is and always will be the major factor affecting condition of rangeland resources (Pieper and Heitschmidt 1988). No grazing system can counteract the negative impacts of long-term overstocking. These conclusions are well backed by various long-term studies from North America (Holechek et al. 2001) and Africa (O'Reagan and Turner 1992).

There can be no argument with Fleischner (1994) and Jones (2000) that poorly controlled livestock grazing can be destructive of rangeland ecosystems. However, these reviews mislead readers by overlooking over 35 controlled grazing studies from North America and over 50 studies from other parts of the world (O'Reagan and Turner 1992, Milchunas and Lauenroth 1996, Ash and Smith 1996) that show livestock grazing managed using scientific principles is sustainable and generally results in rangeland improvement. Fleischner (1994) and Jones (2000) fail to recognize that severe, heavy, moderate, conservative, and light grazing intensities each have different impacts on rangeland ecosystems. Rather than focusing on what is well known (unmanaged grazing is damaging to rangelands), I will now focus on how controlled grazing at light to moderate intensities affects rangelands relative to ungrazed controls. I will selectively review those studies that I judge to have adequate experimental design to separate controlled grazing from climatic, soil, and other environmental effects.

Vegetation Studies

Research Identification

In western North America I have found 20 studies that compare vegetation responses of controlled grazing at moderate to light intensities with grazing exclusion. These studies are summarized in Table 4. Sixteen of these studies evaluated trend, 11 evaluated productivity and 2 evaluated drought responses of lands under managed grazing compared to grazing exclusion. Only 7 of the studies involve arid rangelands.

Analysis of Trend Studies

Fourteen of the 18 studies evaluating trend had sufficient baseline information where vegetation changes through time could be determined. In all 14 of these studies ungrazed and moderately to lightly grazed treatments showed the same trend. Ten studies showed an upward trend, two showed a downward trend, and two showed no definite trend. Paulsen and Ares (1962) reported a downward trend on Chihuahuan Desert rangeland due to extended drought while Skovlin et al. (1976) associated a downward trend on coniferous forest rangeland with increasing tree cover. In 6 of the 18 studies, composition did not differ between grazed and ungrazed areas. Grazed compared to ungrazed areas were considered to be in higher ecological condition (more climax vegetation) in 5 studies and lower in 5 studies. Two studies (Paulsen and Ares 1962, Hart and Ashby 1998) merit special consideration because they involved long-time periods (over 20 years), were well replicated in space, and provided detailed characterization of grazing intensity. In both studies grazing was found to be sustainable at intensities that involved up to 40% utilization of forage.

On the Colorado shortgrass prairie prickly pear cactus (*Opuntia Polyacantha* Haw.) biomass was lowered by 55 years of moderate grazing (40% use) compared to exclusion (Hart and Ashby 1998). Shrub biomass (mostly fringed sagewort [*Artemisia frigida willd.*], slender bush eriogonum [*Erogonum microthecum* Nutt.], broom snakeweed [*Gutierrizea sarothrae* Pursh]) was higher under exclusion than under grazing. The lower cactus and shrub component under grazing treatments was considered advantageous because these plants are associated with retrogression away from the climax plant community and have low forage value for livestock and wildlife. Light and moderate grazing reduced cool-season graminoids but increased warm-season graminoids compared to exclusion. Forb biomass did not differ among grazed and ungrazed treatments. It was concluded that moderate cattle grazing had been sustainable during the 55-year period of study.

In the Chihuahuan Desert of New Mexico black grama (*Bouteloua eriopoda* Torr.)basal cover over a 37-year period was maintained at a higher level under conservative grazing (35% use) than under protection or heavier grazing levels (Paulsen and Ares 1962) (Figure 1). Black grama is the primary decreaser forage grass in the Chihuahuan Desert and dominates upland rangelands in high ecological condition. Tobosa, (*Hilaria mutica* Buckley) is the second most important forage grass in the Chihuahuan Desert and dominates lowland flood plains. Tobosa had over twice as much basal area on long term (15 years) conservatively and moderately grazed quadrats as those protected (Table 5). The authors stated tobosa plants tend to stagnate when old growth is not removed. Moderate grazing is desirable to maintain a vigorous tobosa stand. Findings from the Paulsen and Ares (1962) study are supported by additional follow-up research from the same study areas by Herbel and Gibbens (1996). These two Chihuahuan Desert studies provide strong evidence that managed livestock grazing at light to moderate levels is sustainable in arid environments.

Further evidence that grazing is sustainable in arid environments is provided by Navarro et al. (2002). This study evaluated long term (1952-1999) trend in ecological condition on 41 grazed sites well scattered across Bureau of Land Management rangelands in the Chihuahuan Desert of southern New Mexico. Over the 48 year study period, major changes occurred in rangeland condition due to fluctuations in precipitation. However, at the end of the study, average ecological condition score across sites was the same as at the beginning. The average percent cover of primary forage grasses was the same. The authors concluded managed livestock grazing is sustainable on Chihuahuan Desert rangelands.

Plant Diversity

Very few studies have evaluated the effects of controlled grazing on plant diversity in arid and semiarid areas. In the Chihuahuan Desert of south-central New Mexico, Smith et al. (1996) reported vegetation diversity was higher on long-term conservatively grazed late seral rangeland than on lightly grazed rangeland in near-climax condition. In another study in the same area, Nelson et al. (1997) reported vegetation diversity was the same on moderately grazed mid seral and conservatively grazed late seral rangelands. On the shortgrass prairie of Colorado, Milchunas et al. (1988) found plant diversity increased as grazing intensity decreased. However the difference in plant diversity between ungrazed and lightly grazed areas was small.

Vegetation Productivity

Long term managed grazing compared to grazing exclusion on average reduced grass production 13% and total vegetation production 4% across 11 different studies (Table 6). The Chihuahuan Desert study merits particular consideration because it involved two sites and 19 years of data collection (Herbel and Gibbens 1996). Grazing intensities were conservative (30-35% use of forage). On both sites in this study managed grazing resulted in slightly higher grass production than exclusion. Grazing intensity was lower in this study than in the others cited above. In arid areas it appears that grazing at light to conservative levels may have no effect or a stimulative effect on forage production. This however needs to be better studied.

Two studies provide evidence that long-term grazing exclusion can result in vegetation stagnation. On chaparral rangeland in south-central Texas, Merrill and Reardon (1976) found production of decreaser grasses was lower under grazing exclusion than under a moderately stocked four-pasture deferred-rotation grazing system. On desert shrub rangelands in Nevada, Tueller and Tower (1979) found productivity of desirable shrubs (bitterbrush) was lower but that of grasses higher on grazing excluded compared to grazed areas. This study was not included in Table 6 because information on grazing intensity was vague.

Most of the productivity studies in Table 6 apparently did not use cages on grazed areas to account for herbage removed by livestock. Another problem I encountered in reviewing the studies is that many of them do not clearly state whether old growth was separated from new growth. In the Herbel and Gibbens (1996) study where grass production was slightly higher on grazed areas, the authors do state that their estimates involved only current year growth.

Drought Response

Three studies indicate that light to conservative grazing may actually benefit grass plants during drought compared to no grazing (Johnson 1956, Paulsen and Ares 1962, Ganskopp and Bedell 1981). In eastern Oregon lightly grazed Idaho fescue (*Festuca idahoensis* Elmer) and bluebunch wheatgrass (*Agropyron spicatum* Pursh) had as much and in some cases more herbage, seed stalks and final height than ungrazed plants following severe drought (Ganskopp and Bedell 1981). Similar observations were made for black grama on Chihuahuan Desert rangeland in New Mexico (Paulsen and Ares 1962). On coniferous forest rangeland in Colorado, Johnson (1956) found moderately and lightly grazed pastures had less reduction in forage production than grazing excluded plots during drought. In their book, Sonoran Desert researchers Bock and Bock (2000) reported that moderate livestock grazing reduced drought caused mortality on perennial grasses in southeastern Arizona.

Positive Influences of Controlled Grazing

Possible positive influences of managed grazing compared to grazing exclusion on range plant productivity are reviewed by Holechek (1981), and Holechek et al. (2001). These include removal of excess vegetation that may negatively affect net carbohydrate fixation, maintaining an optimal leaf area index, reducing transpiration losses, reducing excess accumulations of standing dead vegetation and mulch, increased tillering in grasses, reducing apical dominance in shrubs and inoculating plant part with saliva may stimulate growth. Nearly all of the studies identifying these responses were conducted in greenhouses rather than under range conditions. Research by McNaughton (1983) in the African Serengeti provides one of the best validations that grazing does have positive or compensating effects on forage plant productivity while Belsky (1986) reviews contradictory evidence. A major challenge for rangeland researchers in the twenty-first century will be to provide better information on this subject.

Soil and Watershed Studies

In contrast to vegetation, several (over 30) studies are available that have evaluated the effects of controlled grazing versus exclusion on rangeland soils and watershed properties. Various reviews of these studies include Gifford and Hawkins (1978), Branson et al. (1981), Blackburn (1984), Thurow (1991), Heady and Child (1994), and Holechek et al. (2001). Unlike the studies on rangeland vegetation, the research on soils and watershed properties under controlled and grazing exclusion is remarkably consistent. These studies all show that light to moderate grazing reduces soil bulk density, reduces water infiltration, increases overland flow

(Figure 2) and increases soil erosion (Figure 3) relative to grazing exclusion. However, these effects are small and have little lasting impact on rangeland ecosystem health.

A popular belief has been that intensive grazing can loosen the soil surface during drying periods and increase infiltration (Savory and Parsons 1980). Several studies reviewed by Thurow (1991), Heady and Child (1994), and Holechek et al. (2001) are consistent in showing that intensive livestock grazing has caused the opposite effect increasing compaction, reducing infiltration, and increasing erosion.

Short-duration intensive grazing involving concentrated livestock hoof activity for short time periods has been promoted for its capability to improve water infiltration into the soil and increase forage production. The most detailed evaluation of hydrologic responses under short-duration grazing was reported by Warren et al. (1986a,b,c). They studied infiltration and sediment production on a silty clay soil in Texas using a short-duration grazing system with moderate, double-moderate, and triple-moderate stocking rates. Short-duration grazing at all intensities reduced infiltration and increased sediment production compared to no grazing (Warren et al. 1986c) (Table 7). These deleterious effects were increased as stocking rate increased. The damage was augmented when the soil was moist at the time of treading. Thirty days of rest was insufficient to allow hydrologic recovery. Another part of the study evaluated seasonal changes in infiltration and sediment production under short-duration grazing at a moderate stocking rate (Warren et al. 1986a). The infiltration rate declined and sediment production increased following the short-term intense grazing periods inherent to this system. These effects were most severe during drought and dormancy, due to reduced vegetation standing crop. It was also found that there was no hydrologic advantage to increased stocking density via manipulation of pasture size and numbers (Warren et al. 1986b).

Available research is consistent in showing that short-duration grazing increases sediment production compared to moderate continuous grazing (McCalla et al. 1984, Thurow et al. 1986, Weltz and Wood 1986, Pluhar et al. 1987). The reduced vegetation standing crop and cover associated with short-duration grazing appeared to cause the higher sediment production.

Sediment production under various other specialized grazing systems has been compared with moderate continuous grazing (Wood and Blackburn 1981, Gamougoun et al. 1984, Pluhar et al. 1987). As in the case of infiltration, these studies show little difference between grazing systems other than short-duration intensive grazing.

Although treading by livestock can have undesirable effects such as soil compaction, it can also have desirable effects. Treading incorporates standing dead material into the soil surface increasing mineral cycling. It can reduce large accumulations of mulch and litter by incorporating these materials into the soil. Moderate treading by livestock appears to favor emergence and survival of perennial grass seedlings while heavy treading can favor undesirable forbs and shrubs (Hyder and Sneva 1956, Eckert et al. 1986). Like so many things, a small to moderate level of livestock hoof action can be beneficial while heavy amounts are destructive.

Discussions of the role of livestock grazing on mineral cycling are provided by Briske and Heitschmidt (1991), Haynes and Williams (1993), and Heady and Child (1994). Without question, livestock grazing increases the rate of nutrient flow and availability in rangeland ecosystems by biting, chewing, rumination, digestion, urination and defecation. These processes cause a large proportion of essential nutrients otherwise tied up in plant material to more rapidly become available in mineral form to support plant growth. While this is a positive aspect of controlled grazing, a detailed discussion of mineral cycling by livestock is beyond the scope of this paper.

Various types of compensation ameliorate the impacts of light to moderate livestock grazing on rangeland soils. Soil formation is an ongoing process. Natural soil formation compensates to some extent for erosion that occurs under light to moderate grazing. Natural deposition of soil from overland flow of water replaces some of the soil loss from grazing. Activities of insects and burrowing mammals relieve soil compaction from grazing as does scratching and dusting by birds. Termite activity decomposes manure and accelerates nutrient cycling. Soil compaction by grazing animals occurs primarily in the first 5 cm of soil and seldom extends beyond 15 cm (Reynolds and Packer 1963). Alternate swelling and shrinking of soils from wetting, drying, freezing, and thawing can cause complete recovery from heavy treading within 2 to 3 years (Lusby 1970, Stephenson and Veigel 1987). Under light to moderate livestock treading, most rangeland soils are little impacted or recover within a year or less.

Impacts of Controlled Grazing on Rangeland Wildlife

During the last 20 years a vast amount of research has become available on interactions between rangeland wildlife and livestock. Comprehensive reviews of this literature include Holechek et al. (1982), Kie et al. (1994), Krausman (ed.) (1996), and Holechek et al. (2001). The various ways properly managed livestock grazing can positively impact wildlife are summarized by Holechek et al. (1982), Launchbaugh et al. (1996) and Holechek et al. (2001). These include:

1. Increasing diversity of vegetation composition for early to mid successional wildlife.
2. Creating patchy habitat with high structural diversity for feeding, nesting, and hiding.
3. Opening up dense vegetation to create travel corridors for wildlife.
4. Removal of rank, coarse grass to encourage re-growth and improve abundance of high quality forage.

5. Stimulating browse production by reducing grass biomass.
6. Improving nutritional quality of browse by stimulating plant re-growth.
7. Creating weedy patches as feeding sites for upland gamebirds and deer.
8. Creating bare ground as feeding, dusting and display areas for upland gamebirds and songbirds.

Various examples of these positive impacts on individual wildlife species are provided by Holechek et al. (1982), Krausman (ed.) (1994), and Holechek et al. (2001). However, actual studies evaluating how groups of wildlife species on particular rangelands respond to various managed grazing programs are limited. The primary research available on this issue comes from a series of studies in the Chihuahuan Desert of southern New Mexico. These studies compared mammal and bird observations on lightly grazed rangeland in near climax condition, conservatively grazed rangeland in late seral condition, and moderately grazed rangeland in mid seral condition. Lightly grazed climax rangelands and conservatively grazed late seral rangelands had similar songbird and total bird populations but pronghorn, jackrabbit, scaled quail, and mourning dove observations were lower on the climax rangeland (Smith et al. 1996). More species of wildlife, particularly songbirds, were observed on the late seral rangeland. Overall wildlife diversity was higher on the conservatively grazed late seral than the lightly grazed climax rangeland. In a follow up study Nelson et al. (1997) found total wildlife observations were higher on moderately grazed mid seral Chihuahuan Desert rangelands compared to conservatively grazed late seral rangelands (Table 8). Total songbird and jackrabbit observations were higher on the mid seral rangelands. There was some evidence pronghorn preferred the late seral rangelands. Overall wildlife diversity did not differ between mid and late seral rangelands. Nelson et al. (1999) evaluated wildlife preferences for grassland (late seral), shrub-grass (mid seral) and shrubland (early seral) communities in the Chihuahuan Desert of New Mexico. They found total birds, total mammals, and total wildlife preferred shrub-grass over grassland or shrubland. Shrubland communities were preferred over grassland communities. Shrubland communities are favored by heavy livestock grazing, shrub-grass communities are favored by moderate grazing and grassland communities are favored by conservative to no grazing. This series of studies provides strong evidence that conservatively to moderately grazed areas in mid or late seral condition provide better wildlife habitat than ungrazed areas in climax condition in the Chihuahuan Desert. However, some species such meadowlarks, barn owls and aplomado falcons require a high component of grassland habitat. Therefore maintaining a patchwork of lightly, conservatively and moderately grazed pastures appears to provide optimal wildlife habitat in the Chihuahuan Desert and on most other western rangelands.

Similar research to that previously discussed evaluated the response of birds and rodents to grazing exclusion and moderate cattle grazing in southeastern Arizona (Bock et al. 1984). In this study the grazed area supported higher bird numbers during the summer but densities did not differ in winter. Rodents were more abundant on the protected area. It was concluded moderate cattle grazing favors birds over rodents as a class.

In the southwestern United States, Mearns quail are one of the upland gamebirds most sensitive to livestock grazing. Grazing use levels of no more than 35 to 40% of forage appear necessary to maintain Mearns quail populations (Brown 1982). On the other hand light to moderate cattle grazing can benefit Mearns quail by increasing availability of food plants (Brown 1982, Bristow and Ockenfels 2000). An intensive study of Mearns quail habitat in southeastern Arizona showed more Mearns quail coveys occurred on grazed than ungrazed rangelands (Bristow and Ockenfels, 2000). Grazing intensities were considered to be light to moderate on the areas studied. The investigators cautioned that heavy grazing would be harmful to Mearns quail as demonstrated by Brown (1982) through excessive removal of cover and food.

Studies in New Mexico (Campbell et al. 1973, Saiwana et al. 1998) have indicated conservative to moderate grazing can benefit scaled quail by improving their mobility through opening up dense grass stands. However, on severely degraded rangelands any benefits of livestock grazing to scaled quail are doubtful.

Certain rangeland wildlife species such as jackrabbits and prairie dogs are benefited by heavy livestock grazing while others such as bighorn sheep and prairie chickens can be quickly eliminated. However, my analysis of the literature shows most wildlife species are tolerant of moderate grazing and many appear to be benefited by light to conservative grazing. I could find no research showing light to conservative livestock grazing was harmful to any rangeland wildlife species even in arid or semiarid environments. The highest populations of the southwestern willow flycatcher, an endangered songbird species, occur on the U-Bar-Ranch in New Mexico, an area with managed cattle grazing (Stoleson et al. 1998).

Controlled Livestock Grazing Impacts on Riparian Habitat

Several studies reviewed by Ohmart (1996) and Belsky et al. (1999) have demonstrated that poorly managed livestock grazing can be destructive to riparian habitat. Only recently have studies become available comparing the effects of carefully controlled grazing and grazing exclusion on riparian habitat. In eastern Oregon (Shaw and Clary 1995) and central Idaho (Clary et al. 1999) carefully timed cattle grazing at light to moderate intensities had a similar effect on riparian vegetation as grazing exclusion. Many riparian improvements occurred under both controlled grazing and grazing exclusion in the Idaho study (Clary et al. 1999). It was concluded light to moderate cattle grazing in late spring is compatible with riparian habitat maintenance and improvement.

Unfortunately, in the southwestern United States, research evaluating the effects of controlled grazing on riparian habitat is limited. On the Montana Allotment on the Coronado National Forest in southeastern Arizona, a combination of rest rotation grazing and conservative stocking over a 10-year period resulted in rapid improvement of both riparian vegetation and bank characteristics (Fleming et al. 2001). Hundreds of riparian trees became established in riparian reaches where they had been absent 13 years ago. Based on a system using 10 indicators, riparian health on the Montana Allotment was judged to be excellent. This study shows that well planned grazing can result in rapid riparian habitat improvement under some conditions in the southwestern United States.

Controlled Livestock Grazing Impacts on Fish

Very little research addresses fish/grazing relationships in the western United States (Rinne 1999). Much of what is known about the effects of grazing on fishes is summarized by Platts (1991) and Rinne (1999). Scientific consensus, as summarized by Platts (1991), has been that grazing has irrefutably harmed fishes and their habitats. Despite this statement Platt (1991) and Rinne (1999) both acknowledge that controversy exists because published, valid evaluations of grazing strategies as related to fishery productivity are lacking in the literature. Therefore cause and effect are not completely understood between livestock grazing and fishes. After reviewing 166 papers relating to fish and grazing, Rinne (1999) found only 30 that evaluated fish population responses to grazing. The rest were concerned primarily with grazing effects on riparian habitat attributes. After careful dissection, it was found only 3 of the 30 studies contained pretreatment data essential to separate grazing effects from natural variations in populations. Various other experimental limitations were found in these studies such as lack of replication in time and space. Lack of statistical analyses and failure to report in peer reviewed publications were other important limitations.

Nearly all of the literature on grazing and fishes involves upper-elevation, mountain areas inhabited by coldwater salmonid species (Rinne 1999). Knowledge of grazing effects on salmonids (trout) cannot be readily applied to warm-water species (minnows and suckers) occupying lower-elevation streams and rivers because their habitat requirements and behavioral traits differ (Rinne and Neary 1997). Several warm-water fish species are threatened or endangered such as the spikedace and Rio Grande sucker. However lack of research prevents drawing definite inferences about the effects of controlled grazing on this category of fish. Rinne and Neary (1997) found that endangered cyprinid fish populations in the Verde River, Arizona actually disappeared when grazing was excluded. It can be conjectured that grazing strategies that result in riparian habitat improvement will generally benefit salmonid fish species but this may not apply to some warm water fish species.

Conclusions

Several literature reviews have compared the impacts of unmanaged livestock grazing with grazing exclusion on various components of rangeland ecosystems. These reviews are consistent in showing unmanaged grazing can be destructive to rangeland vegetation , soils and wildlife. Unfortunately reviews comparing the impacts of managed livestock grazing to grazing exclusion are limited. My analysis of 20 studies shows carefully managed grazing can have neutral or in some cases positive affects on plant succession, productivity and drought survival.

Although claims have been made that intensive grazing can be beneficial to rangeland soils, over 30 studies are consistent in showing that grazing even at light to moderate intensities adversely impacts soils by increasing compaction, reducing infiltration and increasing erosion. However, the magnitude of these adverse effects is ameliorated by natural forces that cause soil formation, soil deposition, and soil loosening. Treading of soil by livestock can improve grass seeding establishment and increase mineral cycling.

Managed grazing can be beneficial to some desirable wildlife species. Evidence that grazing at light to conservative intensities has harmed or endangered wildlife species is lacking. Recent research shows some riparian habitats can rapidly improve under properly timed grazing at light to conservative intensities. Many claims have been made that livestock grazing adversely impacts fish populations. Poorly controlled grazing can harm habitat of various salmonids but impacts on warm water fish species are uncertain. Research comparing the impacts of carefully controlled grazing versus grazing exclusion on fish populations is lacking. Habitat for salmonids can improve under controlled grazing but grazing exclusion may give a faster rate of improvement.

Today's ranchers in the western United States are under heavy assault from radical environmental groups who want all livestock grazing discontinued on public lands. The case for removal of livestock is being made using a variety of studies and anecdotal evidence that focus on poorly controlled grazing and have serious experimental limitations. These include lack of pretreatment information, lack of replication in time, lack of replication in space, failure to apply statistical tests, and failure to publish in peer reviewed outlets. Well designed long-term studies are needed that better evaluate the impacts of various grazing intensities and systems versus grazing exclusion on rangeland vegetation. Knowledge of how vegetation is impacted by controlled grazing versus grazing exclusion can be readily used in decisions regarding management of watersheds, wildlife habitat, and fish habitat.

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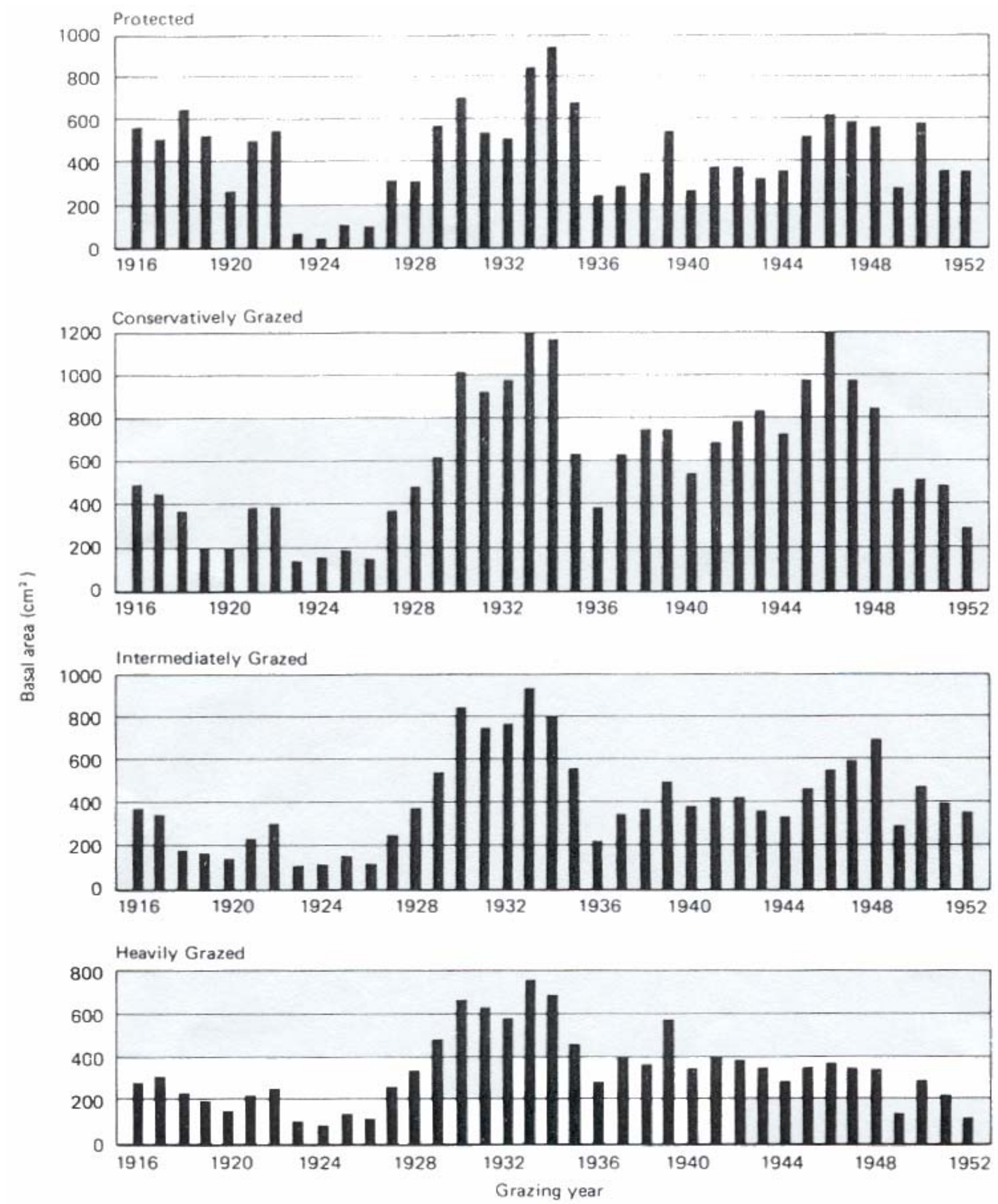

Figure 1. Basal area of black grama on meter-square quadrats protected from grazing and at three intensities of grazing on the Jornada Experimental Range, southern New Mexico, 1916-1953 (From Paulsen and Ares 1962.)

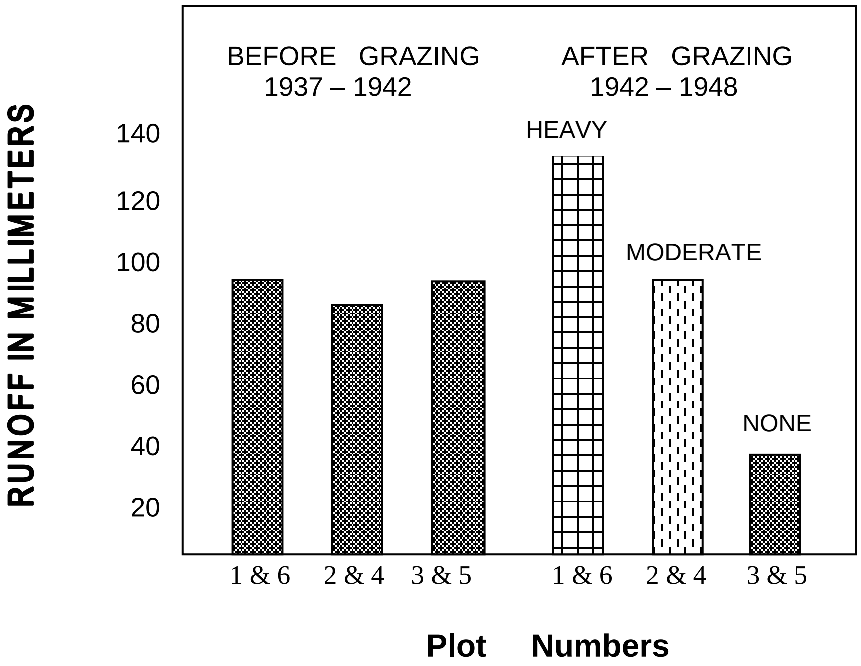

Figure 2. Runoff for bunchgrass rangeland in Colorado prior to grazing (1937–1942) and after (1942-1948) heavy and moderate grazing. (Adapted from Dunford 1949 by Branson et al. 1981.)

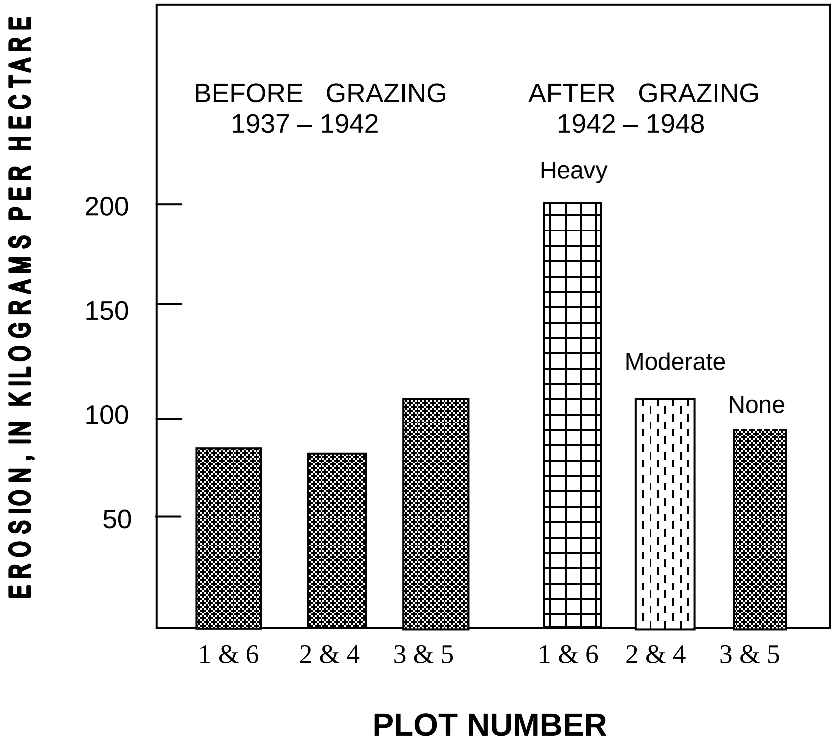

Figure 3. Average erosion from plots subject to different grazing intensities before grazing (1937-1942) and after grazing (1942-1948) on bunchgrass range in Colorado. (Adapted from Dunford 1949 by Branson et al. 1981.)

Table 1. Comparative percentages of Bureau of Land Management rangelands in excellent, good, fair, and poor condition between 1936 and 1998.

YEAR	EXCELLENT (CLIMAX)	GOOD (LATE SERAL)	FAIR (MID SERAL)	POOR (EARLY SERAL)
1936	1.5	14.3	47.9	36.6
1966	2.2	16.7	51.6	29.5
1975	2.0	15.0	50.0	33.0
1984[a]	5.0	31.0	42.0	18.0
1993[a]	4.0	33.0	38.0	14.0
1998[a]	5.0	28.0	39.0	11.0

Source: USDI 184, 1994, 1998.
[a] Less than 100% totals because some lands have not been rated as to range condition.

Table 2. Summary of 25 studies on effects of grazing intensity on native vegetation and livestock production in North America.

	GRAZING INTENSITY		
	HEAVY	MODERATE	LIGHT
Average use of forage (%)	57	43	32
Average forage production (lbs./acre)	1,175[1] (1,065)[2]	1,473[1] (1,308)[2]	1,597[1]
Forage production drought years (lbs./acre)	820[1]	986[1]	1,219[1]
Range trend in ecological condition	down (92%)[3]	up (52%)[4]	up (78%)[4]
Average calf crop (%)	72[1] (77)[2]	79[1] (84)[2]	82[1]
Average lamb crop (%)	78	82	87
Calf weaning wt (lb)	381[1] (422)[2]	415[1] (454)[2]	431[1]
Lamb weaning wt (lb)	57	63	----
Gain per steer (lb)	158	203	227
Steer/calf gain per day (lb)	1.83	2.15	2.30
Steer/calf gain per acre (lb)	40.0	33.8	22.4
Lamb gain per acre (lb)	26.0	20.4	13.8
Net returns per animal ($)	38.06[1] (29.00)[2]	51.57[1] (39.71)[2]	58.89[1]
Net returns per acre ($)	1.29[1] (1.72)[2]	2.61[1] (2.24)[2]	2.37[1]

Source: Holechek et al. 1999a.

[1] Average for those studies comparing heavy, moderate, and light grazing (studies comparing only heavy and moderate grazing excluded).

[2] Average for all studies.

[3] Percentage of studies with downward trend.

[4] Percentage of studies with upward trend.

Table 3. Summary of 15 studies on effects of rotation grazing systems on native rangeland vegetation and livestock production in North America.

CHARACTERISTIC	SEASON-LONG OR CONTINUOUS GRAZING	ROTATION GRAZING
Average use of forage (%)	41.8	42.4
Average forage production (lb/acre)		+7%
Range trend	up=61%, stable=31%, down=8%	up=69%, stable 85, down=23%
Average calf crop (%)	89.4	85.9
Calf weaning wt (lb)	504.6	494.1
Net returns ($/acre)	6.60	6.37

Source: Holechek et al. 1999.

Table 4. Studies comparing vegetation responses of controlled grazing at moderate to light intensities with grazing exclusion.

Range Type	Location	Vegetation Responses Studied	Grazing Treatment	Reference
Northern mixed prairie	Alberta, Canada	Production	Light grazing, Grazing exclusion	Johnston 1962
Northern mixed prairie	North Dakota	Trend	Moderate grazing, Grazing exclusion	Brand and Goetz 1986
Northern mixed prairie	Alberta, Canada	Trend	Grazing intensities, Grazing exclusion	Smoliak et al. 1972
Northern mixed prairie	Montana	Trend	Conservative stocking, Grazing exclusion	Vogel and Van Dyne 1966
Southern mixed prairie	Texas	Productivity, Trend	Stocking rates, Grazing systems, Grazing exclusion	Wood and Blackburn 1984
Southern mixed prairie	Texas	Trend	Stocking rates, Grazing systems, Grazing exclusion	Thurow et al. 1986
Southern mixed prairie		Productivity, Trend	Stocking rates, Grazing exclusion	Heitschmidt et al. 1985
Southern mixed prairie	Texas	Productivity, Trend	Stocking rates, Grazing systems, Grazing exclusion	Reardon and Merrill 1976
Shortgrass prairie	Colorado	Productivity	Stocking rates, Grazing exclusion	Milchunas et al. 1994
Shortgrass prairie	Colorado	Trend	Stocking rates, Grazing exclusion	Hart and Ashby 1998
Coniferous forest	Colorado	Productivity, Drought response Trend	Stocking rates, Grazing exclusion	Johnson 1956, Smith 1967
Coniferous forest	Oregon	Productivity, Trend	Stocking rates, Grazing systems, Grazing exclusion	Skovlin et al. 1976
Palouse bunchgrass	Oregon	Productivity, Trend	Stocking rates, Grazing systems, Grazing exclusion	Skovlin et al. 1976
Sagebrush grassland	New Mexico	Trend	Moderate stocking, Grazing exclusion	Holechek and Stephenson 1983
Sagebrush grassland	Idaho	Trend	Timed grazing, Grazing exclusion	Bork et al. 1998
Sagebrush grassland	Oregon	Drought response	Grazing intensity, Grazing exclusion	Ganshopp and Bedell 1981
Chihuahuan Desert	New Mexico	Trend, Drought response	Grazing intensities, Grazing exclusion	Paulsen and Ares 1962
Chihuahuan Desert	New Mexico	Productivity, Trend	Conservative grazing, Grazing exclusion	Herbel and Gibbens 1996
Salt Desert	Utah	Trend	Grazing timing, Grazing exclusion	Alzerreca-Angelo et al. 1998
Mojave Desert	Utah/Arizona	Trend	Grazing intensity, Grazing exclusion	Jeffries and Klopatek 1987

Table 5. Average basal area of tobosa (cm^{-2}) on square meter quadrats receiving 4 different intensities of cattle grazing in the 1928 to 1943 period on Jornada Experimental Range in southern New Mexico (Paulsen and Ares 1962).

Grazing Intensity	Use of Forage (%)	Average Basal Area of Tobosa (cm^{-2})
Protected	0	1,191
Conservative	<40%	2,461
Intermediate (Moderate)	40-55%	2,718
Heavy	>55%	2,294

Table 6. Summary of studies evaluating vegetation productivity under controlled grazing and grazing exclusion in North America.

			Grass Productivity			Total Vegetation Productivity		
			Grazed	Excluded		Grazed	Excluded	
			$kg\ ha^{-1}$		% Difference	$kg\ ha^{-1}$		% Difference
Johnston 1962	Alberta, Canada	Northern mixed prairie	1,390	1,625	-14	2,429	2,471	-2
Brand & Goetz 1986	North Dakota	Northern mixed prairie	1,540	1,780	-13	1,908	1,908	-8
Vogel & Van Dyne 1966	Montana	Northern mixed prairie	477	522	-9	655	733	-11
Wood & Blackburn 1984	Texas	Southern mixed prairie	3,281	4,202	-22	-----	-----	-----
Heitschmidt et al. 1986	Texas	Southern mixed prairie	1,152	1,430	-19	1,171	1,441	-19
Reardon & Merrill 1976	Texas	Southern mixed prairie	1,211	1,015	+14	2,436	1,578	+54
Milchunas et al. 1984	Colorado	Shortgrass	710	750	-5	-----	-----	-----
Johnson 1956	Colorado	Coniferous forest	733	1,229	-40	982	1,637	-40
Skovlin et al. 1976	Oregon	Coniferous forest	900	160	-37	196	337	-17
Skovlin et al. 1976	Oregon	Palouse prairie	175	204	-14	374	350	+7
Herbel & Gibbens 1996	New Mexico	Chihuahuan desert	215	206	+4	-----	-----	-----
Average			999	1,193	-13	1,250	1,294	-4

Table 7. Infiltration rate and sediment production in relation to stocking rate and soil water content at the time of trampling on the Edwards Plateau, Texas (from Warrant et al 1986c).

STOCKING RATE	TRAMPLED DRY	TRAMPLED MOIST
INFILTRATION RATE (MM/HR.)		
0	166	160
1X	140	133
2X	121	99
3X	117	96
SEDIMENT PRODUCTION (KG/HA)		
0	976	2,007
1X	2,827	2,875
2X	3,438	4,274
3X	4,788	5,861

1X = moderate stocking rate, 2X = double-moderate stocking rate, 3X = triple-moderate stocking rate.

Table 8. Average wildlife sightings (sightings km^2) on conservatively grazed late seral and moderately grazed mid seral rangelands in southern New Mexico (From Nelson et al. 1997).

Wildlife species	Late Seral/Conservatively Grazed	Mid Seral/Moderately Grazed
	--------------------------(Sightings km^2)	-----------------------------
Pronghorn	9.3	0.5
Coyote	0.5	3.1
Jackrabbit	49.1	63.4
Cottontail	8.1	12.4
Total Mammals	67.1	79.6
Mourning dove	12.4	19.3
Scaled quail	8.1	16.2
Total Gamebirds	20.5	35.5
Meadow lark	5.2	14.9
Western kingbird	18.0	20.5
Loggerhead shrike	6.2	13.1
Sparrow/juncos	110.7	138.7
Mockingbird	6.2	14.9
Lark bunting	20.5	42.9
Other songbirds	4.9	23.9
Total songbirds	171.7	268.7
Total raptors	13.1	16.8
Ravens	10.1	11.8
Total other birds	10.6	12.4
Total birds	215.9	333.4
Total wildlife	282.0	413.0