Predation on goats also results in other, less tangible effects. Goats use many browse plants that are relatively unacceptable to cattle and sheep and can be used to control low-growing brush and sprouts after brush has been reduced by chemical or mechanical means. Control of brush can increase soil moisture and activate springs or increase their flow rate. Grazing a mixture of livestock species often allows greater total stocking rates than does grazing by a single species and also can be beneficial to wildlife. In general, diversification of enterprises with cattle, sheep, and goats allows producers to reduce economic risk and permits the flexibility to shift to alternate livestock or crops in response to changing prices, costs, labor availability, and predation. Potential economic returns resulting from proper grazing management and brush control can be significant.

In addition, predation disrupts the social life of ranch families. Family outings may be planned and anticipated only to be cancelled because coyotes have been killing livestock and efforts must be made to reduce predation. Similarly, if predation becomes serious when ranchers are preoccupied with other, time-critical production activities, such as pecan spraying or oat planting, they must decide which has the highest priority and neglect the others. For example, if they continue to spray pecans or plant oats, they risk a serious loss of livestock. If they stop farming activities in order to protect livestock, they may lose part of their crop. Thus, ranchers sometimes operate under excessive stress at times when a decision either way can be extremely costly. While it is difficult to quantify economic and social costs of such factors, they are real and can be severe.

In summary, most studies have underestimated the impact of predation on farm and ranch enterprises since only economic costs associated with deaths were recorded. However, this study of data from one Texas goat ranch and pertinent literature has identified other significant effects which are generally overlooked. These include the costs of animal injuries and/or deaths, management and other procedures used to reduce predation, the inefficient use or loss of forage resources, and other less tangible effects such as the inability to use goats for brush control and added personal stress from constant concern about predation. Consideration of these costs is essential to determine the potential benefits of Angora goat production and the potential costs of predation.

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Evolutionary Implications for Grazing Management Systems

Karen A. Platou and Paul T. Tueller

This paper is meant to deal with grazing systems, an old and complicated topic lying at the heart of range management. In taking readers through a thought process, using simplified and sometimes theoretical concepts, it is hoped that they will be left with new insight on the connection between natural and managed grazing systems, and ecosystem-herbivore interactions in general.

Over time, plants and animals coexisting within a given set of environmental conditions become ecologically dependent through the process of evolutionary selection. In designing grazing systems for livestock production, it may be helpful to look first at how native ungulates and plants have coevolved, thereby generating natural grazing systems. Comparison and evaluation of salient plant and animal features resulting from evolution can suggest characteristics which should be retained in a livestock system to maintain the efficiency inherent in natural grazing systems. This comparison is illustrated with two important North American grazing regions, the Great Basin shrub-steppe, and the Great Plains mid and short grass prairies (Table 1).

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The authors welcome comments from others on statements which to some may not clearly support applied and theoretical viewpoints, or which may seem overly speculative.

Great Basin:

The sagebrush-steppe covers over 138 million acres of intermountain cold desert rangeland, from eastern California, across Nevada to western Utah, and from south-eastern Oregon to northwestern Arizona. The range type is classed as Great Basin sagebrush and sagebrush-steppe. Soils underlying the sagebrush vegetation are mostly Aridisols. The arid climate is characterized by an average annual precipitation of 8 to 12 inches but annual variation is on the order of 20%. One-half or more of this precipitation comes as snow during the winter (West 1983). During late spring and summer, essentially no surface-penetrating rains occur. The ground becomes increasingly drier as evapotranspiration is intensified by warm southwesterly winds. Growing conditions are even more limited than the average 100-day frost free period because of inadequate moisture.

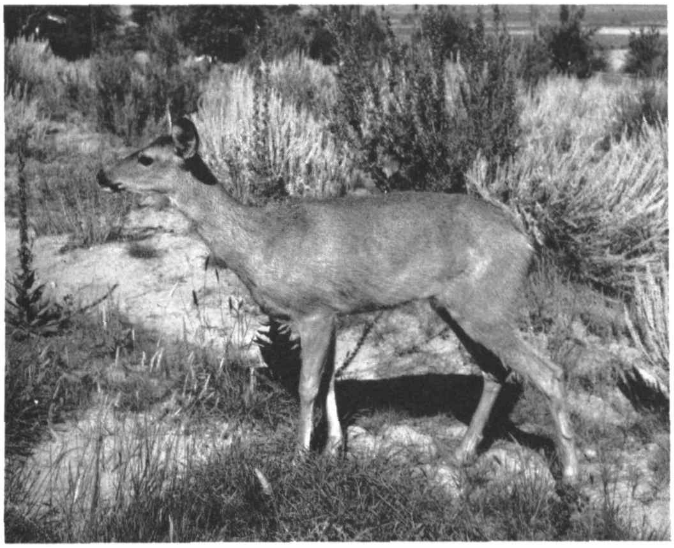
As the name implies, the Great Basin shrub steppe is dominated by a mix of brush and grass species adapted to the prevailing climatic and soil conditions. The grasses, which tend to be of the cool-season type, grow rapidly during a

Table 1. The Great Basin Cold Desert Shrub-Steppe and Great Plains mid and short grass prairies compared.

	Desert shrub-steppe	Mid-shortgrass prairie
Abiotic Environment		
-elevation	3500–10,000 ft	2000–3500 ft.
-topography	flat valley bottoms to steep mountainous	flat to rolling, very gradual elevation change
-soils	mostly Aridisols	mostly Mollisols
-precipitation	8–12 in (elev. (dependent)	18–24 inches
-seasonal distribution of precip.	winter and spring (aridic)	winter, spring and summer (ustic)
-frost free period	0–120 days (elevation dependent)	90–120 days
Vegetation general		
-dominant	shrubs/grasses	grass
-distribution of individuals	clumped or dispersed	continuous
-biomass grasses	low (240–1200 lb/ac)	high (650–2400 lb/ac)
-life form	cespitose bunchgrass	sod-forming
-reproduction	seed	vegetative
-storage	above and below ground	largely below ground
-predominant photosynthetic pathway	C3 - cool season high palatibility high nutritious no silica bodies less fibrous less water efficient	C4 - warm season low palatibility lower nutrition silica bodies fibrous more water efficient
	low reproduction and production potential; need to rest to recoup stores after grazing.	*reduced loss of stores due to grazing, enhanced growth in somes cases as response to grazing.*
Native Ungulates		
-species	deer, pronghorn, sheep	bison, elk, pronghorn
-social organization	solitary or small bands	large herds
-movements	seasonal migration territorial	continual migration non-territorial
-food habits	selective browsers high quality, low quantity high selectivity	generalist grazers low quality, high quantity low selectivity
	low intensity, moderate duration, high selection	*high intensity, short duration, low selection*

short growing season using stored soil moisture, produce seed, and then go dormant in the dry period. They are primarily bunchgrasses growing in clumped or dispersed distributions, and are quite palatable to herbivores. Grass biomass productivity is mostly above ground and energy stores become rapidly depleted with successive clipping (Ellison 1960). Grasses must compete with shrubs for moisture, nutrients, and light. The shrubs, dominated by sagebrush, are of limited palatability to cattle. However, several native wildlife species, especially pronghorn antelope and mule deer, rely heavily on browse when succulent herbs are not available.

All of the native ungulates of the Great Basin exhibit physiological and behavioral adaptation to their habitat, in accordance with their selective preference for forbs and browse. Elevational differences are responsible for pronounced variation in the advent of spring green-up and the availability of forage. As a result, animals extend their effective grazing season by undertaking seasonal elevational migrations. Once in their seasonal ranges, the ungulates distribute themselves widely in small groups in order to find their dispersed forage. Because of the scarcity of food resources these animals have adapted morphologically for selectivity. Many of the animals have a small body size which dictates that they eat small amounts of highly nutritious forage. Small muzzles and sharp senses allow mule deer,



Mule deer, a selective browser in the Great Basin shrub-steppe. (photo by Jim Yoakum)

bighorn sheep and pronghorn antelope to distinguish and select the most palatable and nutritious portions of forage plants. Selective foraging also influences the social organization of the animals. Deer and sheep are found in small family groups or bands which are territorial within summer and winter ranges. Pronghorn antelope exhibit a certain amount of territoriality during the summer months when bucks defend groups of does and fawns or wander singly between bands (Yoakum 1978).

The carrying capacity of the sagebrush steppe for large ungulates is low and historically was even lower. Based on historical and paleontological evidence, grasses were more prevalent in the Great Basin in the past. Much of this forage resource was underutilized by large herbovires (Young et al. 1976). The large ungulates found in the Great Basin were largely selective browsers, preferring shrubs growing on the fringes of the sagebrush-steppe at higher elevations. These included mule deer, pronghorn antelope and bighorn sheep. Young et al. (1976) report that pronghorn antelope populations were not high enough to support drives by the Deep Creek Goshute Indians more frequently than once a decade. Early European explorers reported the pronghorn antelope to be much less abundant throughout the Great Basin than in the short-grass plains.

Great Plains:

Extending from the Rocky Mountains eastward across eastern Colorado, Montana, Kansas, Nebraska, the Dakotas and south to Texas are the mid- and short-grass prairies of North America. The topography of the area is rolling with only gradual elevation changes from 3,500 ft. in the west to 2,000 ft. in the eastern portion. The prairie soils are typically Mollisols. The climate of the area may be classed as semiarid with average annual rainfall totals between 18 and 24 inches. Most of the precipitation comes as spring and summer rain coinciding with an average 165-day frost-free period.

The short- and mid-grass prairies, in contrast to the Great Basin, support an almost continuous cover of primarily sod-forming grasses with few forbs and shrubs intermixed. Among other influences, the continuous distribution of vegetation affects water infiltration and retention. Water is intercepted by vegetation, reaching the soil along the stems. The fibrous root system aids water infiltration by increasing the porosity of the soil and by providing surfaces for water movement through the profile. More efficient use of available water by alternate photosynthetic pathways allows warm-season grasses to extend their growing season where precipitation is common throughout the summer. As long as water is available and temperatures are adequate, the predominant warm-season (C4) grasses replace tissues lost by clipping more quickly than cool-season (C3) plants of the Great Basin (Caswell et al. 1973).

C4 plants are also seemingly more resistant to grazing than the C3 plants. C4 plants incorporate silica bodies in their tissues, are more fibrous, and have lower nutritional content than C3 grasses (Caswell et al. 1973, Schwartz and Ellis 1981). These characteristics make them less palatable to herbivores (Caswell et al. 1973). Grasses of the short and mid grass region store much of their biomass at groundlevel or underground in the form of stolons and rhizomes. They are able to withstand frequent defoliation by grazing without loss of stores. Rhizomes and stolons are the primary means of reproduction. Seed production is not as crucial for maintaining the stand unless the area is completely denuded, e.g., disturbed areas around watering sites.

Since the late Pleistocene extinction of many large herbivores, the fauna of the plains has been quite constant. For example, the distribution of bison has coincided closely with that of the plains grassland for the last 5,000 years (McDonald 1981). Until the coming of European man as hunters, farmers and ranchers, the plains supported populations of bison and pronghorn estimated at between 30 and 40 million for each species (Nelson 1925). Bison were ideally suited to grassland life in their physiology and behavior. They were generalist grazers, which because of their body size, required large amounts of forage daily. Their wide mouths grazed a swath of vegetation that resulted in a non-selective choice of forage without particularly high nutritive quality. Because of their high forage requirement, the bison had to travel almost continually in their search for forage and could not be discriminating in their food habits. Bison, like other plains animals moved in large social groups, presumably as protection from danger in open country. Seasonal and short term migrations were tied to forage availability (Meagher 1978). Seasonal flooding, fire and the unevenness of rainfall patterns, as well as grazing effects of other animals and the influence of predators including the Plains Indians, caused the bison to use different areas at different times during the grazing season.

Bison, generalist grazers of the mid and short grass prairie. (photo by Jim Yoakum)

Following the bison herds were often large groups of pronghorn antelope, traveling in bands of does, yearlings and fawns in summer, then grouping into wintering herds in excess of 500 animals (Yoakum 1978). Larger wintering concentrations are found in the plains in comparison to the Great Basin. Theoretically, this is possible since the continuous distribution of grasses and forbs used as winter feed on the Great Plains makes them easier to obtain than the dispersed, low quality sagebrush used in the Great Basin (Jarman 1974).

Elk, although preferring semi-timbered country bordering the vast treeless expanses, were numerous on the plains. They too are gregarious generalist grazers. Summer herds of elk up to 400 animals were common, and in winter concentrations of over 1,000 were possible (Boyd 1978).

Mule deer and bighorn sheep populations on the Plains were relatively small and their distribution restricted to areas with uneven topography and sufficient brush cover. These species are less well adapted to open country with predominantly grass forage.

Comparison

Looking back at these features of the plains and shrub-steppe flora and fauna, we can see two natural grazing systems emerging. Herd effect on the Great Plains creates the attributes of low selectivity, heavy grazing pressure, trampling, dunging and urinating in a concentrated area. This activity is important in the cycling of nutients in the soil and in the dissemination, germination and establishment of seeds, particularly in high use areas (McNaughton 1979). The requirement for forage quantity ensures that herds do not remain in any one area for very long and that they do not return to the same area until the forage is adequate to meet the energy requirements of grazing. *The essence of this "system" is high-intensity, short-duration grazing.*

On the shrub-steppe, animals are more dispersed. Animals remain on their ranges for a long period of time because of the scattered distribution of their food plants and their lower requirement for bulk. Animals make up for lack of quantity by grazing selectively on more nutritious plants or plant parts. A large portion of the forage resource is shrubby browse, reducing the grazing impact on grasses. Plants growing in the Great Basin cannot withstand repeated heavy grazing pressure in part because of the shorter growing season; however, with the low animal density, the same individual plant is less likely to be grazed at the same time each year, allowing for seed set and accumulation of carbohydrate storage in some years. *The longer rest period between grazing periods for these lower producers is the key feature of this natural system.*

Not too surprisingly these two natural grazing systems incorporate the same principles as two well-known modern grazing systems designed for livestock production. When Gus Hormay designed the rest-rotation grazing system he had the physiological needs of the cold-desert shrub steppe grasses in mind (Hormay 1970). Likewise, Allan Savory designed a grazing approach which would take advantage of the beneficial effects of high intensity, short-duration grazing including: non-selective grazing, trampling and dunging (Savory and Parsons 1980).

But these grazing methods are not equivalent to natural ecosystems. Not only have domestic livestock been introduced but also domestic ideas such as pastures, fences, supplemental feeding and water. When we consider the introduction of cattle either in addition to or as replacement for native animals, we see that although cows share characteristics with several wild species, they most closely resemble bison both physically and behaviorally. In designing a grazing method which takes advantage of the social and foraging behavior of our primary livestock animal. Savory was aware of the animal component of the system and possibly was perceptive of how it might have coevolved with certain vegetation communities predominated by warm-season grasses with longer growing seasons and available summer moisture.

What happens when we impose a high-intensity, short-duration grazing method on the shrub-steppe which did not coevolve with a generalist herbivore? Grasses of the shrub-steppe have not developed the traits such as stolons and rhizomes (Mack and Thompson 1982) necessary to preserve carbohydrate reserves under this type of grazing pressure. Grazing-intolerant bunchgrasses will be lost with repeated heavy grazing every year due to the lack of reproduction and inadequate carbohydrate storage under a growing season which is too short to allow adequate regrowth and storage. The required recovery period is too long to accommodate repeated grazing cycles per season; only a full season rest every few years allows for maintenance of bunchgrasses.

Better alternatives to implementation of high intensity grazing systems are needed in the Great Basin and they are suggested by observation of the natural grazing systems: (1) Plants need adequate growing season rest so a rest-rotation grazing system such as that developed by Hormay (1970) is appropriate if large numbers of cattle are to be grazed seasonally without damage to the vegetation. (2) Changing animal behavior by breeding for selective foraging and for territoriality could produce cattle that resemble in their grazing patterns the wild animals with which the ecosystem evolved. The Zimmerman Ranch, in central Nevada, has followed this technique, raising cattle on the range which are best suited to the prevailing natural conditions. These cattle utilize browse primarily; they range widely in rough terrain grazing throughout the year in small groups of at most 20 animals. Production efficiency does not appear to have been compromised although riding time is increased over that for ranches using standard cattle breeds. (3) Another approach to the problem of matching the grazing system to the coevolved ecosystem revolves around the development of a marketplace for managed wild animals native to the system. Ranching deer, or perhaps exotic game animals (West 1983), which are better suited for efficiently harvesting plant material from the ecosystem than cattle, might be an alternative to managing for cattle if economic feasibility can be established.

Just as the high-intensity, short-duration method is largely incompatible with the Great Basin ecosystem for the foregoing reasons, the rest rotation system has met with only limited success on warm-season prairie grass ranges. Since the grasses of the plains have evolved under heavy grazing pressure they do not require the rest supplied by rest rotation and in fact may show a reduction in both vigor and productivity as a result of full season rest. Advantages of rest-rotation systems over continuous grazing has not been realized. Certainly the higher yield resulting from shorter rest periods is worth a great deal in the economic sense so long as plant vigor is not sacrificed.

It ought to be recognized that the two most highly touted grazing management systems in the United States are closely related to natural systems that have evolved within the framework of specified environmental biotic and abiotic variables. In the future, studies should be directed toward greater understanding of various natural grazing systems. For by understanding their evolutionary nature we can better predict the success of imposed contemporary grazing management systems and design new intensive systems that will allow more efficient use of our rangelands.

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Defoliation Effects on Three Range Grasses

Alastair McLean and Sandra Wikeem

Knowledge of a plant's period of greatest susceptibility to defoliation injury is necessary to promote sound grazing management. Clipping trials were conducted on three of southern British Columbia's most important grassland range grasses to determine the periods of highest sensitivity to herbage removal. The clipping trials were more severe than most grazing situations but did serve to highlight weak points in the growth cycle sooner than grazing trials would have.

The three grasses studied were bluebunch wheatgrass, rough fescue and crested wheatgrass. Bluebunch wheatgrass reaches the northern limits of its distribution on the grasslands of southern British Columbia. It occurs as the main grass on many sites from low elevations in the Big Sagebrush-Bluebunch Wheatgrass zone (Brown Chernozemic soils) in the valley bottoms to the Bluebunch Wheatgrass-Rough Fescue zone on Black Chernozemic soils near the forest edge. Rough fescue, which occupies a niche similar to Idaho fescue farther south, can produce up to one-half the dry matter yield on the productive Bluebunch Wheatgrass-Rough Fescue zone. It seldom reaches its full production potential, however, being highly preferred by cattle during the growing season and quickly decreases on overgrazed ranges. Crested wheatgrass is the most widely seeded grass for range improvement programs in the drybelt of southern British Columbia, particularly on low elevation spring-fall ranges. The species is highly valued for its characteristics of early growth, high production and resistance to drought and grazing.

Clipping trials were conducted at two upper grassland sites for rough fescue, two lower grassland sites for crested wheatgrass and one site each in the upper and lower zones for bluebunch wheatgrass. The onset of the clipping treat-

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Editor's Note: This paper is a condensation of two papers by the authors which appear in the *Journal of Range Management* in 1985. It shows what will potentially happen if the grasses are overgrazed.