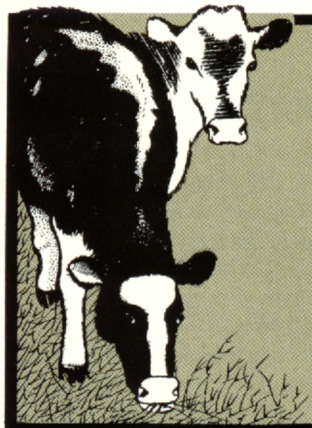

Managing Livestock Grazing on Meadows of California's Sierra Nevada

A Manager-User Guide

Seasonal aspects at Tule Meadow, Sierra National Forest, California in 1983.

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The Authors:
Raymond D. Ratliff is Range Scientist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Fresno. Melvin R. George is Range and Pasture Specialist, UC Cooperative Extension, Davis. Neil K. McDougald is Livestock and Range Farm Advisor, UC Cooperative Extension, Madera County.

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Introduction

Mountain meadows in California's Sierra Nevada Mountains have been concentration points for livestock, wildlife, and people for more than 100 years. For herbivores, they provide abundant forage and for people scenic vistas and camp sites. Meadows also filter sediments from watersheds and stabilize streambanks, providing clean water downstream. The resource manager's job is to strike an optimal balance among various, possibly conflicting uses. The resource user's job is to work with management and other users to define the product mix to be produced and to assure maintenance of resource productivity.

This guide emphasizes management of livestock grazing, the dominant economic use of meadows. Meadow production and degree of use information are summarized as a guide to establishing proper use. Meadow production by elevation—5,000, 7,000, 9,000, and 11,000 feet—is related to meadow hydrologic type—wet, moist, and dry—and meadow range condition—excellent, good, fair, and poor. Based on production estimates for each hydrologic type, grazing capacities and desirable amounts of herbage residue are estimated.

In addition, range readiness dates are estimated for different elevations by kind of year—dry, normal, and wet. Length of the grazing period is discussed in relation to carbohydrate storage, weather, and current use. These guidelines should be carefully evaluated for applicability to specific local conditions as they represent broad generalizations.

Basics

Meadow types

Description and classification of Sierran meadows and meadow sites is an on-going process (Benedict 1983; Benedict and Major 1982; Heady and Zinke 1978; Kosco 1980; Ratliff 1982, for example). The following summarizes a recent system of meadow classification (Ratliff 1985).

Major categories of the system are subformations, series, and associations. The subformation to which a meadow (or meadow site) belongs is defined by its margin type (vegetated or sandy), plant belt (subalpine or montane), and topographic position (basin, slope, or stream). Within subformations, meadow series are defined according to hydrologic properties and/or vegetation.

The six hydrologic classes of the system are:

- **Raised-convex**—a site (with an enclosed open-water surface) occurring as a mound above the surrounding meadow.
- **Hanging**—a site occurring on a slope and constantly watered by flows from springs and seeps.
- **Lotic**—a site characterized by moving water and constantly watered by flows from upstream.
- **Sunken-concave**—a site characterized by ponded water and seasonally recharged by flows from upstream.
- **Normal**—a site that obtains water from the water table, is recharged by precipitation, and may dry in the surface during summer.
- **Xeric**—a site occurring on a slope or bench, seasonally recharged by precipitation, and becoming quite dry during summer.

Sites of raised-convex, hanging, lotic, and sunken-concave series define the wet meadow type. Normal and xeric sites define the moist and dry meadow types, respectively.

Vegetative series are general classes intended to reflect abundance of major species. They are based on current, rather than potential or climax vegetation. Associations are composed of sites of the same hydrologic and vegetative series that are similar in species composition.

Where meadows occur

Meadows occur in basins, on slopes, and along permanent or intermittent streams. Basic requirements for meadows are watershed area and slope relationships that promote accumulation of fine-textured materials and geologic strata that promote constancy in hydrologic flows. Basin meadows occur in natural depressions and where dikes, moraines, or other obstructions stop or slow downstream flows (fig. 1). Slope meadows occur below seeps or springs where percolating water contacts an impervious layer and emerges on the surface (fig. 2). In both situations, low-flow velocity tends to promote deposition, permitting vegetation to grow in the channel. Stream meadows also form behind obstructions and

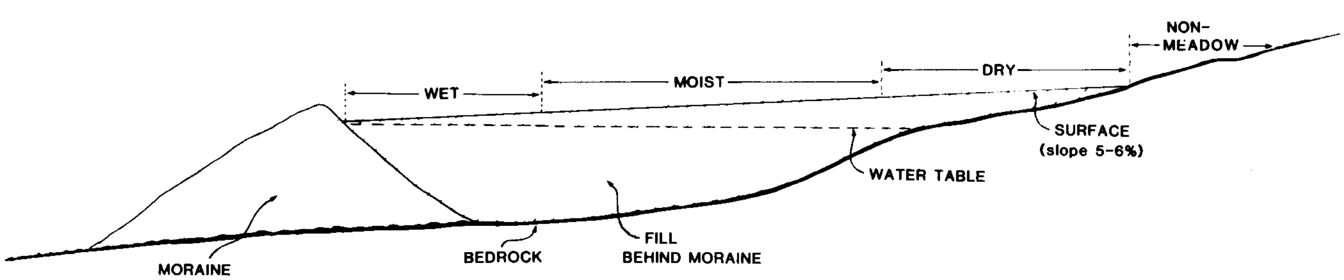

Fig. 1. Schematic longitudinal section of a basin-type meadow with approximate locations of hydrologic classes.

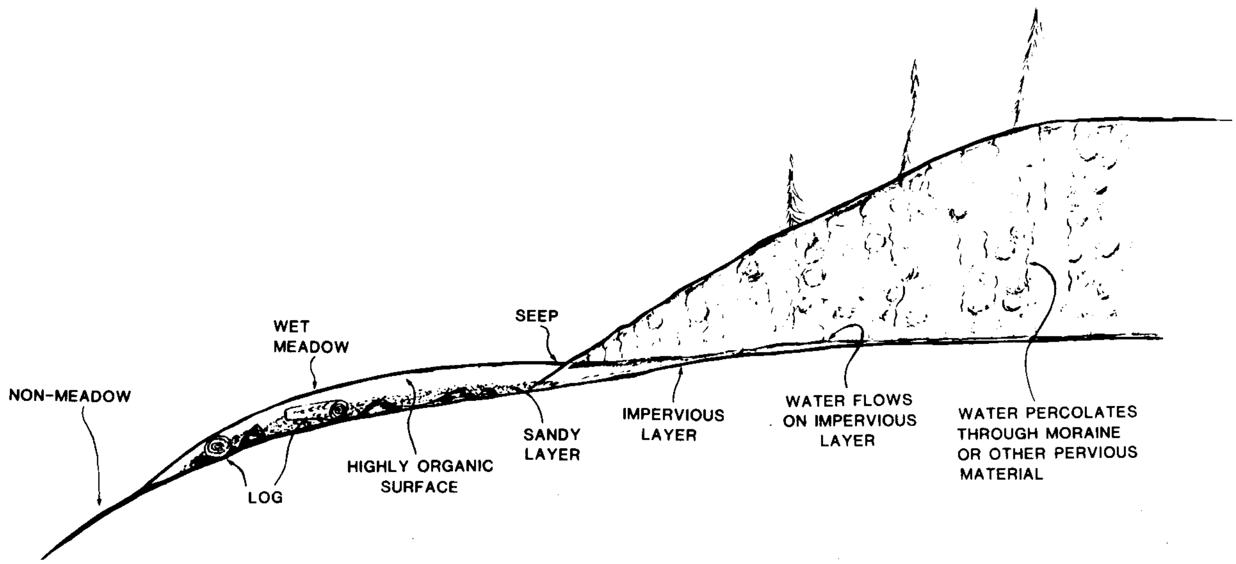

Fig. 2. Schematic longitudinal section of a slope-type meadow.

below seeps. But higher flow velocity tends to promote transport, keeping the channel clear of vegetation.

Seasonality

Each year (whether grazed or ungrazed) the appearance of a meadow changes with advance of the season (cover photo). Just after snow melts, residue from the previous year is not fully decomposed, and the meadow looks brown and mucky. However, growth is rapid and the meadow soon takes on a fresh green appearance. Depending on the site and elevation, a sequence of wildflowers may appear. At Tule Meadow Jeffrey shooting star *(Dodecatheon jeffreyi)* is followed by American bistort knotweed *(Polygonum bistortoides)*. Like spring flowers in a bed bordering a lawn, the blossoms of each species last a few days, then fade. Grass and grasslike plants mature, and the meadow is no longer colorful or bright green. Frosts turn the meadow brown or reddish once again.

Grazing alters the visual aspects of meadows. Different species of flowers may appear if grazing has significantly reduced the density of grass and grasslike plants. With reduced foliar cover, light reaches lower into the canopy, permitting smaller flowering plants such as primrose monkeyflower *(Mimulus primuloides)* and hooded ladies tresses *(Spiranthes romanzoffiana)* to grow and bloom. Also, removal of older leaves, tillering, and regrowth keep the meadow green later into the fall.

Range management

Meadows are much like lawns. Withhold the water or mow a lawn too closely and too often and grass declines while weeds increase. But when well watered and properly mowed, a lawn produces abundant herbage from spring to fall. There are few weeds, and the grass is thick.

A basic requirement for good range management of meadows is proper use (Range Term Glossary Committee 1974). Proper use of meadows is the degree and time of use of meadows and associated watersheds which, if continued, either maintains or restores meadow ecological integrity and is consistent with conservation of other natural resources (Ratliff 1985). When the degree and time are correctly coordinated, use of meadow resources will not exceed threshold levels that could cause damage, and the potential for damage from extrinsic factors (water velocity and sediment load, for example) is lowered.

To determine proper use, the manager must know how much forage is produced, how much of that production can be grazed, and when it can be grazed without impairing future production. Obtaining such knowledge is difficult on rangelands with fairly constant elevation and vegetation. Add the complexities of changes in elevation, hydrology, and vegetation found in meadows of the Sierra Nevada in California and the problems of determining proper use expand greatly.

Herbage Production

What is known

Herbage productivity is related to elevation, meadow hydrology, vegetation type, and grazing. Meadow productivity generally decreases as elevation increases, decreases toward the extremes of the moisture gradient, peaks when vegetation is at or near climax, and decreases as range conditions decline. Maximum productivity is achieved by those vegetation types that occur on more mesic sites (A. Giffen, C. M. Johnson, and P. Zinke, unpublished progress report for 1969 on an ecological study of meadows in lower Rock Creek, Sequoia National Park).

Elevation effects. An acre of meadow at high elevation can support fewer cow months (CM) than an acre of meadow at lower elevation. Cow months per acre decline from 3.4 at 5,500 to 6,000 feet to 1.7 at elevations of 8,500 to 9,000 feet (Crane 1950). That effect mainly results from shorter growing seasons and naturally less productive plant communities at higher elevations.

Similar trends were found in Sequoia National Park and the Sierra National Forest. At 9,450-foot elevation, meadow productivity across vegetation types was 1,695 pounds per acre. At 11,600 feet productivity was 312 pounds per acre (A. Giffen, C. M. Johnson, and P. Zinke, unpublished progress report for 1969 on an ecological study of meadows in lower Rock Creek). At Markwood Meadow (elevation 5,800 feet), forage production was estimated at 3,739 to 4,508 pounds per acre (Clayton 1974; Pattee 1973). At Exchequer Meadow (elevation 7,280 feet), forage production was estimated at 1,280 to 2,963 pounds per acre.

Hydrologic and vegetation effects. Meadow hydrology largely determines the potential species composition (Hormay 1943). This leads to an interaction of hydrology and vegetation type expressed in meadow production. Slender spikerush *(Heleocharis pauciflora)* and beaked sedge *(Carex rostrata)* sites generally are wetter and lower producing than sites with Nebraska sedge *(Carex nebraskensis)* and tufted hairgrass *(Deschampsia caespitosa)* (table 1). Slender spikerush *(Heleocharis acicularis)* sites occur as ephemeral lakes at relatively low elevations. Shorthair *(Calamagrostis breweri)* sites occur at relatively high elevations and are mesic or moist. Sites with short-hair sedge *(Carex exserta)* are the driest and highest.

Grazing and condition effects. Grazing of herbage by livestock and wildlife affects production by stimulating the reduction of some plant species and the increase of others. As the proportions of different plant species in the community change, open ground may increase and further decrease production.

Plant species can be categorized as decreasers, increasers, and invaders (Dyksterhuis 1949; Stoddart, Smith, and Box 1975). Decreaser species are usually major constituents of the composition at climax; they decrease in the stand with overgrazing. Increaser species are usually minor constituents of the composition at climax; they increase in the stand, at least initially, with overgrazing. Invader species are not part of the climax vegetation. They increase in the stand with overgrazing and are often associated with reduced cover and with lowered production.

Forage production and grazing capacity partly reflect range condition—"the current productivity of a range relative to what that range is naturally capable of producing" (Range Term Glossary Committee 1974). Differences in productive capabilities—hence, conditions—are not, however, always indicated by the proportions of increasers and decreasers present. While species composition may change, increasers like Kentucky bluegrass

TABLE 1. Ranges in herbage production for seven meadow vegetation series of the Sierra Nevada, California*

Vegetation series	Sites studied	Range in herbage production (lb/acre)		
		Low	Average	High
Beaked sedge	7	1,300	1,650	2,100
Slender spikerush	2	800	1,000	1,250
Tufted hairgrass	5	1,500	2,400	3,200
Nebraska sedge	3	2,150	2,800	3,650
Fewflowered spikerush	1	350	1,150	2,250
Shorthair	28	600	1,050	2,000
Short-hair sedge	11	150	300	400

*Based on Ratliff (1985).

(Poa pratensis) are desirable, highly productive forage species. Individual shoots of some decreasers produce more herbage than those of some increasers, but the opposite situation also occurs. Therefore, per unit of composition, amounts of herbage produced by different species or species groups may be about the same. For example, 1 percent of the foliar composition equals 11.2 pounds per acre for grasslike plants, 10.8 pounds per acre for grasses, and 12.1 pounds per acre for forbs (Sanderson 1967).

Production estimates

Wet meadows. Basic production estimates (table 2) were derived from CM per acre data presented by Crane (1950) as CM/ac × 800 lb/0.65. Allowable use was set at 65 percent—Crane used 60 to 70 percent. A cow month (CM) was assumed equivalent to an animal unit month (AUM)—the amount of forage, about 800 pounds, required by an animal-unit—one 1,000-pound cow—for 1 month (Range Term Glossary Committee 1974).

Relative reduction in herbage production with poorer meadow conditions was considered approximately constant for all elevations (Crane 1950). Reductions in herbage production from excellent to good, fair, and poor condition meadows were estimated as 35 percent for excellent to good, 56 percent for excellent to fair, and 75 percent for excellent to poor.

Excellent condition wet meadows around Rae Lakes in Kings Canyon National Park (10,600-foot elevation) averaged 1,681 pounds per acre in 1971 (R.D. Ratliff, unpublished). Relationships among the condition classes were used to estimate herbage production for other conditions at that elevation. Herbage production was estimated at 1,090 pounds per acre for good, 739 pounds per acre for fair, and 420 pounds per acre for poor condition meadows.

Regardless of condition, the negative effect of elevation on herbage production of wet meadows was assumed to be approximately linear. We regressed the derived production estimates on elevation by condition class. We used the regression coefficients to estimate wet meadow herbage production at elevations of 5,000, 7,000, 9,000, and 11,000 feet for each condition class (table 3).

TABLE 2. Estimated herbage production (lb/ac) for different condition classes of wet meadow at various elevations*

Condition class	Elevation (ft) 5,750	6,250	6,750	7,250	7,750	8,250	8,750
Excellent	4,185	3,815	3,569	3,323	3,077	2,338	2,092
Good	2,708	2,462	2,338	2,215	1,969	1,477	1,354
Fair	1,846	1,723	1,600	1,477	1,354	985	862
Poor	1,034	960	898	837	775	578	517

*Based on Crane (1950).

TABLE 3. Estimated wet meadow productivity, minimum amounts of residual herbage,* and grazing capacity† by condition class and elevation

Condition class	Elevation (ft) 5,000	7,000	9,000	11,000
Excellent				
Herbage production (lb/ac)	4,500	3,400	2,300	1,150
Residual herbage (lb/ac)	2,900	2,200	1,500	750
Grazing capacity (AUM/ac)	2.0	1.5	1.0	0.5
Good				
Herbage production (lb/ac)	2,900	2,200	1,450	750
Residual herbage (lb/ac)	2,050	1,550	1,050	500
Grazing capacity (AUM/ac)	1.1	0.8	0.6	0.3
Fair				
Herbage production (lb/ac)	2,000	1,500	1,000	450
Residual herbage (lb/ac)	1,500	1,100	750	350
Grazing capacity (AUM/ac)	0.6	0.5	0.3	0.2
Poor				
Herbage production (lb/ac)	1,100	850	550	300
Residual herbage (lb/ac)	900	700	450	250
Grazing capacity (AUM/ac)	0.3	0.2	0.2	<0.1

*Based on leaving 65 percent of average annual production for excellent condition, 70 percent for good condition, 75 percent for fair condition, and 80 percent for poor condition.
†Based on a forage requirement of 800 lb/AUM.

Moist meadows. Data from nine areas in the Sierra National Forest and Sequoia and Kings Canyon National Parks (R. D. Ratliff, unpublished) estimate herbage production for excellent condition moist meadows. The areas range in elevation from 5,800 to 10,600 feet. Production on those areas regressed on their elevations provide estimates of herbage production at the 5,000-, 7,000-, 9,000-, and 11,000-foot elevations for excellent condition moist meadows (table 4). Extrapolation from wet meadow relationships provides estimates of production for the other condition classes.

Dry meadows. Low elevation data are not available for dry meadow types. However, the average standing crop from three short-hair sedge *(Carex exserta)* sites at Rae Lakes (Ratliff 1974) provide a reference point. Those sites are at or slightly above 10,600-foot elevation and in good condition. The average, 357 pounds per acre, provides an estimate of good condition dry meadow herbage production at 11,000 feet (table 5).

Good condition dry meadow herbage productions at 5,000-, 7,000-, and 9,000-foot elevations are estimated from the 11,000-foot value and proportions among estimates for good condition wet meadows. For excellent, fair, and poor condition dry meadows, herbage production is extrapolated—as for moist meadows—using wet meadow relationships.

Degree of Use

What to measure?

Herbage removed and herbage left are counterparts of production. Removing too much of the production too often results in meadow deterioration. Leaving too much of the production too often may, however, have adverse effects on meadow products other than livestock. Abundance of meadow wildflowers, for example, is greater under free choice than under rest-rotation grazing (Ratliff 1972), and some forbs preferred by mule deer are favored by cattle grazing (Holechek 1982). Wild grazers do well on tender young growth, but nutritional deficiencies may occur on mature herbage (Dasmann 1966). By removing old mature herbage, fall livestock grazing can improve spring forage for mule deer (Willms et al. 1979), and a well designed grazing plan can improve forage quality for elk on winter range (Anderson and Scherzinger 1975).

Several authors report the benefits of leaving some amount of the current herbage (Bement 1969; Bentley and Talbot 1951; Heady 1956; Hooper and Heady 1970;

TABLE 4. Estimated moist meadow productivity, minimum amounts of residual herbage,* and grazing capacity† by condition class and elevation

Condition class	Elevation (ft) 5,000	7,000	9,000	11,000
Excellent				
Herbage production (lb/ac)	4,800	3,800	2,750	1,750
Residual herbage (lb/ac)	2,650	2,100	1,550	950
Grazing capacity (AUM/ac)	2.7	2.1	1.6	1.0
Good				
Herbage production (lb/ac)	3,100	2,450	1,800	1,150
Residual herbage (lb/ac)	1,850	1,450	1,100	700
Grazing capacity (AUM/ac)	1.6	1.2	0.9	0.6
Fair				
Herbage production (lb/ac)	2,100	1,650	1,200	750
Residual herbage (lb/ac)	1,350	1,100	800	500
Grazing capacity (AUM/ac)	0.9	0.7	0.5	0.3
Poor				
Herbage production (lb/ac)	1,200	950	700	450
Residual herbage (lb/ac)	850	650	500	300
Grazing capacity (AUM/ac)	0.5	0.4	0.3	0.2

*Based on leaving 55 percent of average annual production for excellent condition, 60 percent for good condition, 65 percent for fair condition, and 70 percent for poor condition.
†Based on a forage requirement of 800 lb/AUM.

TABLE 5. Estimated dry meadow productivity, minimum amounts of residual herbage,* and grazing capacity† by condition class and elevation

Condition class	Elevation (ft) 5,000	7,000	9,000	11,000
Excellent				
Herbage production (lb/ac)	2,150	1,600	1,100	550
Residual herbage (lb/ac)	1,400	1,050	700	350
Grazing capacity (AUM/ac)	0.9	0.7	0.5	0.2
Good				
Herbage production (lb/ac)	1,400	1,050	700	350
Residual herbage (lb/ac)	1,000	750	500	250
Grazing capacity (AUM/ac)	0.5	0.4	0.3	0.1
Fair				
Herbage production (lb/ac)	950	700	500	250
Residual herbage (lb/ac)	700	550	350	200
Grazing capacity (AUM/ac)	0.3	0.2	0.2	<0.1
Poor				
Herbage production (lb/ac)	550	400	250	150
Residual herbage (lb/ac)	450	300	200	100
Grazing capacity (AUM/ac)	0.1	0.1	<0.1	<0.1

*Based on leaving 65 percent of average annual production for excellent condition, 70 percent for good condition, 75 percent for fair condition, and 80 percent for poor condition.
†Based on a forage requirement of 800 lb/AUM.

Hormay 1944). This remaining herbage is directly related to the subsequent ability of plants to regrow.

Historically, range managers have focused on degree of use to evaluate livestock grazing. Degree of use is "the proportion of current year's forage production that is consumed and/or destroyed by grazing animals" (Range Term Glossary Committee 1974). It is the usual measure of how nearly herbage removal approaches allowable use—an estimate of proper degree of use. Degree of use = herbage used/production. The amount of herbage used cannot, however, be estimated directly. It must be estimated from estimates of herbage production and residue (current production minus current use).

We suggest that knowing the residual herbage figure can help a manager to better estimate when proper degree of use is reached. Yearly estimation of production and degree of use is not feasible on operating ranges. Even for research purposes, the need to cage plots and regrowth problems usually restrict estimates of production to selected sites. If production cannot be adequately estimated, the degree of use cannot be adequately estimated either. Residual herbage can be estimated directly and accurately by the harvest, ocular estimate, or double sampling methods. And there is no need to reconstruct what was produced.

Stubble heights and ungrazed height-weight relationships can be used to indicate when herbage use is proper (McDougald and Platt 1976). Stubble heights can also be used to estimate residual herbage (Heady 1975). However, they should be related to weight per unit area, and the relationships should be developed for specific kinds of meadow sites.

Residual herbage tells what?

Residual herbage is a reliable first indicator of proper grazing management. However, it does not tell whether meadow condition is improving or will improve under current management. That requires more detailed range condition and trend analysis. Residue must be left after grazing for the range to sustain production (Stoddart, Smith, and Box 1975). When annual inputs of residual herbage exceed decomposition, the mulch layer increases and soil organic matter content stabilizes. But when annual inputs are less than decomposition, the mulch layer and soil organic matter are depleted and instability results. Altering the amounts of residual herbage also affects species composition and production. As amounts of less desirable species increase in the stand, production of desirable forage usually decreases. And less desirable species increase when residual herbage is not enough.

Residual herbage and grazing capacity estimates

Ideas of how much of the production should be left vary. The 50-50 rule-of-thumb, graze half—leave half is often used. Stubble height data indicate that 40 to 60 percent of the production usually remains (Heady 1975). Grazing capacity estimates are based on 40 percent use (Sanderson 1967) and imply 60 percent residue. Residual amounts are estimated as 56 percent of production at Markwood Meadow and 63 percent at Exchequer Meadow (Clayton 1974). Residues on meadows at Blodgett Forest vary by site but average 41 percent of production (Kosco 1980). And less than 20 percent of the peak standing crop remains on riparian meadows in Oregon (Gillen, Krueger, and Miller 1985).

In alpine meadows, desired residual herbage should equal the proportion of production that decomposes annually (Ratliff 1976, 1980). That is, production-allowable use = annual decomposition = proper residue amount. Decomposition of herbage in litter bags averaged 65 percent per year for a wet meadow and a dry meadow (Ratliff 1980). For three mesic meadow sites, decomposition averaged 55 percent per year. Using those percentages, we estimated the proper residue amounts for excellent condition meadow sites (tables 3, 4, and 5). We suggest leaving 5 percent more of the production for each successive lower condition class (allowable use is 5 percent less).

We consider our estimates to be conservative guides. Proper amounts of residual herbage for specific situations will differ—each situation should be evaluated on its own. Experience and condition trend analysis will tell whether enough residue is being left to maintain or improve the site.

Herbage not needed for site maintenance can produce animal products. The forage requirement for estimating stocking is 800 pounds per AUM. And from production and residual herbage, grazing capacities by meadow types and conditions are estimated as: AUM/ac/yr = lb/ac/yr production − lb/ac/yr residual herbage/800 lb.

In parts of the Sierra Nevada, grazing by kinds of livestock other than cattle is important. Different kinds of animals affect the numbers that may safely be permitted. To determine numbers it is necessary to convert AU in cows to AU in terms of other animals. Common animal-unit conversion factors are 1.25 for horses, 0.2 for sheep and deer, and 0.17 for goats (Heady 1975). Therefore, a meadow that supports 2.0 AUM/ac will support 1.6 horse-unit months, 10 sheep- or deer-unit months, or 11.8 goat-unit months per acre.

Grazing capacity for livestock needs to take wildlife forage requirements and preferences into account. However, because wildlife and livestock do not select identical diets, an AUM for a cow will seldom equal an AUM for deer. Where the carrying capacity for deer or cattle alone is 1 AUM, the carrying capacity when grazed together will be between 1 and 2 AUM depending on the degree of dietary overlap.

Time of Use

What is known

Grazing period is "the length of time that livestock are grazed on a specific area," and range readiness is "the defined stage of plant growth at which grazing may begin under a specific management plan without permanent damage to vegetation or soil" (Range Term Glossary Committee 1974).

On meadows of the Sierra Nevada, the proper grazing period is influenced by three major considerations for plants: carbohydrate storage for early spring growth, effects of weather on regrowth before winter and current use, and soil conditions.

Carbohydrates. In spring, stored carbohydrate sources in shoot bases, roots, and rhizomes are used to support new growth. Developing leaves and shoots use more carbohydrates than they produce during photosynthesis and, therefore, are sinks for carbohydrates.

Replenishing carbohydrate reserves to support initial spring growth is essential. Grazing intensity and frequency will influence regrowth and carbohydrate replacement. Plants that are grazed too heavily and too frequently may enter dormancy with depressed reserves. When sufficient reserves are not available for winter respiration and early spring growth, plants lose vigor and may die, reducing density and productivity. Typical mountain meadow "on dates" of early July may coincide with normal spring carbohydrate reserve depression in Nebraska sedge in some years, depending on elevation and prevailing spring weather (Steele, Ratliff, and Ritenour 1984).

Nevertheless, when proper amounts of herbage residue are left, sufficient reserve replenishment can be expected.

Weather. Duration of the snowpack and times of warming and cooling generally govern when plant species of meadows in the Sierra Nevada reach given growth stages. Plant development is delayed 1 day for each 100 feet of altitude and 4 days for each degree of latitude northward (Stoddart and Smith 1955). The delay for each 100-foot rise may be up to 1.5 days, and a delay of 10 to 15 days in plant development may be expected on north slopes compared to south slopes (USDA, Forest Service 1969).

Regrowth of grasses and grasslike plants is largely due to leaf replacement through tillering (Dahl and Hyder 1977), and abundant carbohydrate production is necessary for tillering. With adequate soil moisture, warm days and cool nights should stimulate tillering, regrowth, and carbohydrate storage. Generally, tillering decreases under moisture stress (Langer 1963). In the Sierra Nevada summers are usually warm and dry, summer rains are infrequent, and fall rains are not dependable. Nevertheless, moist and wet meadows normally have sufficient soil moisture for regrowth. By midsummer, lack of soil moisture may restrict regrowth on dry meadows. Warm days with their higher light intensities have positive effects on growth. Cool nights favor tillering more than warm nights (Langer 1963; Laude 1972).

Current use. The higher net photosynthesis (gross photosynthesis – respiration) the more carbohydrate that is available for plant productivity. Leaf area index (LAI) is the ratio of leaf area to ground area. There is an optimum LAI where net photosynthesis is maximized. At lower leaf areas available solar radiation is not efficiently used. At higher leaf areas shading decreases gross photosynthesis and increases respiration. Both situations reduce net photosynthesis. These considerations relate directly to residual herbage.

Just as there is an optimum LAI for maximum net photosynthesis, there is an optimum range of residue levels for maximum daily dry matter production. Below that range, photosynthetic rate is depressed due to reduced interception of solar radiation. Above that range, photosynthetic rate is depressed due to shading of lower leaves. Furthermore, New Zealand research indicates that animal performance is influenced by residue levels (Rattray and Clark 1984). At low residue levels, animal performance is limited by rate of forage intake. At high residue levels, animal performance is limited by forage quality or rate of intake or both.

A properly grazed meadow should, therefore, have a more favorable LAI for tillering and fall regrowth than an ungrazed meadow. But if few photosynthetically active leaves remain, adequate regrowth and carbohydrate production and storage will be slow or nonexistant.

Soil. Trampling, "the damage to plants or soil brought about by movements or congestion of animals" (Range Term Glossary Committee 1974), is sometimes considered a more important factor in time of use than plant growth and phenology. At range readiness soil moisture should be sufficiently low that animals do not leave deep imprints (Heady 1975). When growth and phenology standards for range readiness are proper, no lasting damage should occur under normal grazing activities. The type of meadow site is important. Generally, meadows with abundant rhizomatous species, such as Nebraska sedge, withstand trampling well. Meadows with abundant bunchgrass species, such as tufted hairgrass, are more easily damaged. Proper time of use for bunchgrass sites may, therefore, require greater attention to the soil factor of range readiness.

Start of grazing period

Range readiness dates are estimated for elevations from 5,000 to 11,000 feet (table 6). The estimates are based on information from Tule Meadow on the Sierra National Forest and a 15-day delay per 1000 foot increase in elevation. Phenology and soil moisture conditions are important determinants of range readiness. Although residue height is an important factor, range readiness is heavily influenced by growth stage of important species and by accessibility of the meadow due to snow cover and soil moisture conditions. Range may be judged ready for grazing when Nebraska sedge flowers or when tufted hairgrass inflorescences are in the boot stage (USDA, Forest Service 1969). Range readiness, based on Nebraska sedge occurred nearly a month later at Tule Meadow in 1980 than in 1981.

By matching photographs from Tule Meadow, we approximated the dates Nebraska sedge reached range readiness for 1980 through 1985. On the average, that stage occurred on June 1. The 95 percent confidence interval placed the true mean between May 9 and June 23.

Amount of precipitation is related to time of range readiness (table 7). The 1978-85 (July to June) average at Wishon Dam, a few miles from Tule Meadow, was 59.9 inches. Precipitation in 1983 was 56 percent above that average but 45 percent below that average in 1985. June 1 was, therefore, taken as the time of range readiness for normal precipitation years at the elevation

TABLE 6. Estimated range readiness dates for meadows of the Sierra Nevada by type of year and elevation

	Type of moisture year*		
Elevation *(ft)*	Dry	Normal	Wet
7,120†	May 9	June 1	June 23
5,000	April 7	April 30	May 22
6,000	April 22	May 15	June 6
7,000	May 7	May 30	June 21
8,000	May 22	June 14	July 6
9,000	June 6	June 29	July 21
10,000	June 21	July 14	Aug. 5
11,000	July 6	July 29	Aug. 20

*These dates vary up to 2 weeks due to differences in latitude and aspect.
†Tule Meadow, Sierra National Forest.

(7,120 feet) of Tule Meadow. The lower confidence limit, May 9, was taken as representing range readiness in dry years. And the upper confidence limit, June 23, was taken as representing range readiness in wet years.

End of grazing period

Plant requirements for regrowth and carbohydrate storage—not hunting seasons or fall storms—should govern the grazing period's end.

The last grazing of meadows previously grazed should be in the fall when nights are cool and days are warm. Those conditions should be expected to continue for 3 to 4 weeks, and ample green leaf tissue should be left to support regrowth before winter. Amount of green tissue will usually be ample when the amount of residue is at or near the proper amount. With the residual herbage composed mostly of photosynthetically active leaves, regrowth should restore sufficient carbohydrates for spring growth.

For meadows not previously grazed in the current season, a fall grazing should be early enough to permit regrowth as well as carbohydrate replenishment. The residual herbage will have relatively few productive leaves.

TABLE 7. Precipitation at Wishon Dam and approximate dates of range readiness at Tule Meadow, Sierra National Forest, California

Year	Precipitation *(in)*	Range readiness
1980	70.7	June 19
1981	36.4	May 27
1982	69.4	June 2
1983	93.5	June 29
1984	43.2	May 2
1985	33.3	May 15

How Should Meadows Be Grazed?

Basics

We are back to the lawn. For maximum herbage production it should be mowed to maintain optimum residue (leaf area), removing excess growth as it is produced (Younger 1972). Meadow grazing management should have a similar objective. And after grazing, good condition meadows should appear to have been mowed (Reid and Pickford 1946).

As early as herbage is sufficient for the animals and normal livestock movements will not cut the sod, herbage on a meadow should be grazed—leaving an amount of herbage near that needed for maintenance or improvement. The objective is to produce an abundance of young leaves efficient in carbohydrate production. Subsequent grazings should strive to maintain both situations. The final grazing should be timed to assure adequate carbohydrate storage for spring growth and needed residue amounts.

Grazing systems

Grazing systems have a place in meadow management. They can be designed to make livestock grazing a positive influence on other meadow values, for example —deferred grazing to improve wildlife habitat. For any grazing system (or management plan) to succeed managers and users must, however, work together. Good range management for meadows requires: trust, agreement, and commitment; establishing reasonable, attainable objectives or goals; proper use of resources; restoration efforts; determining condition and monitoring trend in condition; and user education.

The reason for imposing grazing systems on meadows or grazing allotments is usually improved distribution. Unless their movements are restricted, livestock graze certain range areas and certain plants or plant species, or both, in similar yearly patterns. Such preferential grazing is a major cause of range deterioration (Hormay and Talbot 1961). Grazing systems are used to break the use patterns and counter the effects of preferential grazing, and Ratliff (1985) suggested their use, where possible. Nevertheless, attention to management for proper residue levels should minimize the need for complex grazing systems.

Where a grazing system is used, it must be keyed to plant requirements and be designed for specific objectives (improving meadow condition, spring wildflower shows, or quality deer forage, for example). Requirements of different species cannot be ignored. Sod-forming species, like Nebraska sedge and Kentucky bluegrass, produce new plants from rhizomes as well as seed. They seldom need to produce seed to maintain viable populations. Variations in weather from year to year usually cause breaks in use patterns. Therefore, season-long (or free-choice) grazing, when well managed, is adequate.

Caespitose species, such as tufted hairgrass and slenderbeak sedge *(Carex athrostachya),* depend more on seed for producing new plants. Maintaining viable populations of caespitose species often requires managing for adequate seed crops and to promote seedling establishment. Breaks in use patterns due to weather may not be sufficient to meet those objectives. Some form of deferred and/or rotational grazing may be called for. Keep such systems as simple as will meet the objectives.

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