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Principles of Obtaining and Interpreting Utilization Data on Rangelands

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An earlier version of this paper by the same authors was peer-reviewed and published in 2005 by The University of Arizona Cooperative Extension as "Principles of Obtaining and Interpreting Utilization Data on Southwest Rangelands" (AZ1375). The current paper has been modified slightly to (1) make it generally applicable to all rangelands, and (2) to clarify some concepts that have been misinterpreted since the first paper was published. There has been no change in the principles, concepts, or conclusions expressed in the original paper.

Introduction

Utilization has been an important "tool" in range management since its beginnings. On the surface the concept appears simple, referring to the percentage of current forage removed by grazing animals or the amount of residual vegetation left after grazing. In reality it is complex in concept and in practice, and there has long been controversy over its proper application. There is a large body of information published over the past 75 or more years on methods of measuring utilization and its proper interpretation in rangeland management.

In spite of all the research and discussion on the topic, there is still concern in the range profession that utilization measurement and interpretation is often done inappropriately. Scharnecchia (1999) concluded that the utilization concept is fundamentally flawed and should be discarded, although he offered no practical alternative to it. Part of the problem may be that procedures established for employing utilization data to manage livestock grazing have been extended to issues for which they are not appropriate. Another aspect may be that land management agency personnel include a wider array of disciplines than in past years, and some of these people have limited knowledge of the history and literature on utilization.

In recognition of the concern of range professionals over inappropriate use of utilization concepts, in 1999 the Society for Range Management (SRM) adopted the following position statement:

Use of Forage Utilization and Residue Measurements The Society for Range Management recognizes and endorses forage utilization and residue measurements as useful tools in rangeland monitoring and acknowledges their value in land management. When used with other monitoring information, utilization can be employed to design and evaluate management decisions. These measurements, when properly timed and conducted using appropriate methods and sampling procedures, can be used as an aid in:

1. *Analyzing distribution of animal use on a management unit.*
2. *Interpreting cause and effect relationships for observed changes in resource attributes such as soil cover, species composition, residual cover, etc.*
3. *Adjusting stocking rates and/or timing of grazing when used in conjunction with other monitoring information including: long term vegetation or habitat data, current and historical stocking records, precipitation records, etc.*

Utilization and residue measurements are not management objectives. They are tools to be used with other information in evaluating whether desired resource conditions are being achieved.

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The purpose of this paper is to set forth the fundamental principles of collecting and using utilization data for guiding management on rangelands that are established and accepted by the range management profession, and that are consistent with the stated position of the Society for Range Management. It is meant to clarify how and when utilization can be used in the management of rangelands for livestock grazing. Nothing in this paper should be interpreted to support or endorse the implementation of rigid utilization guidelines in land use plans or terms and conditions of grazing permits.

Percentage utilization will be emphasized rather than stubble height or residual measurements. Use of stubble heights in riparian areas has recently been addressed in another publication (Univ. Idaho Stubble Height Review Team 2004). While related, stubble height estimates are not necessarily a substitute for utilization and the two concepts are different ecologically (Interagency Technical Reference 1999). Stubble height may be related to two primary processes of concern. One is the effect of grazing on the physiological response of the individual plant. The other is the effect of residual vegetation in protecting the soil from wind or water erosion. For example, residual measurements in California annual grasslands have largely focused on soil protection and provision of the proper germination environment during the following season to maintain desirable plant species composition in the community (Bartolome et al. 2002). In this case, they are not related to the physiological response of the plants being grazed as is usually the case where utilization is measured on perennial grasses and shrubs. Additionally, some types of residual cover guidelines (e.g. "structure" requirements or visual obstruction estimates for upland bird nesting) are neither utilization nor stubble height measurements, and will not be addressed here. Detailed protocol for specific data collection methods also will not be addressed because a number of excellent sources exist for this purpose. The emphasis will be on use of utilization data for livestock grazing management in a multiple use framework with the objective of maintaining or improving vegetation cover and/or composition.

Background

Utilization is the proportion or degree of current year's forage production that is consumed or destroyed by animals (including insects). Utilization may refer either to a single plant species, a group of species, or the vegetation as a whole. (Interagency Technical Reference 1999). This definition is virtually identical to that of the SRM (Society for Range Management 1989), and is generally accepted by range professionals. However, Smith (in Western Coordinating Committee 40 and 55 1998) pointed out that this definition may not adequately address two rather different meanings of utilization that have long been recognized. Stoddart and Smith (1955, p 138) state:

> *Utilization of a range means the degree to which animals have consumed the usable forage production expressed in percentage. This production should be based on animal-months consumed compared to animal-months available when the range is correctly used. When dealing with an individual plant, however, utilization has a different usage and is defined as the degree to which animals have consumed the total current herbage production expressed as a percentage. These two uses are confusing and will require clarification whenever the term is used. It is suggested that range use might be a better term for the first meaning and percentage utilization better for the second meaning."*
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> *Neither the definition given above nor common usage makes a clear separation between the two concepts included in the term "utilization.*

The history of the application of utilization in range management may shed some light on this confusion. It appears that utilization concepts were first employed on the Coconino National Forest in Arizona in about 1910 when James Jardine developed the "ocular reconnaissance" approach to range survey (Chapline and Campbell 1944). That procedure was designed to estimate carrying capacity of rangeland as a basis for adjudicating grazing on the national forests, and was later employed as the Interagency Range Survey. The procedure used to estimate the amount of useable forage on a range was based on the concepts of key species and proper use factors. A key species was a palatable and relatively abundant species upon which management was based. Proper use of the key species was the percentage of utilization of current annual production that could be used while maintaining the vigor and productivity of the species on the range. Proper use factors (PUF) were established for other species based on the relative preference or palatability of those species compared to the key species. (PUFs were originally called preference or palatability ratings). Usually PUFs for other species were lower than the key species, but some "ice cream" plants had higher PUFs than key species. This range survey procedure also provided for "utilization adjustments" to be applied to the allowable utilization for all species to reflect distance from water, slope, restricted access, etc. This range survey method, therefore, established the basis for proper use, key areas, and accounting for differences in the amount of forage available depending on animal distribution and dietary preference (as affected by season or kind of animal). However, the method did not involve measurement of utilization.

Interest in estimating utilization began in the 1930s as a means of documenting grazing intensity on grazing allotments and in grazing research. Most of the research and development of utilization measurement techniques was done by Forest Service researchers, especially in the Southwest (Ruyle 2003). Various methods were developed including visual estimates of overall use classes, clipping or weight estimates comparing grazed/ungrazed situations, measuring remaining stubble height or twig length and conversion to utilization based on height/weight relationships, relating percentage of plants or stems grazed to percentage weight removed, and others. Many

variations of these methods were developed to deal with differences in vegetation and monitoring objectives. Heady (1949) provides a review of the various methods and approaches to estimate utilization and little has changed since his review. His observation that "the real problem is not the measurement of use…but the interpretation of those measurements" continues to be the crux of the issue.

Many studies were carried out to obtain actual data to establish "proper use" levels as a basis for interpretation of utilization measurements. These studies were of two general types: (1) grazing studies at different stocking rates to relate average utilization to observed trends in ground cover, plant species composition, and livestock performance, and (2) clipping studies to measure growth response of individual plants to top removal at different intensities, frequency and seasons. These types of studies have served as an empirical basis for developing general guidelines on "proper use." General conclusions about results of these studies are presented in a number of references, including Holechek, Pieper and Herbel (1998); Vavra, Laycock and Pieper (1994); and Heitschmidt and Stuth (1991). Responses at both the individual plant and pasture level vary depending on plant species and/or communities, environmental conditions, and management systems employed so that the prediction of a relationship between utilization and desired management outcomes still depends as much on professional judgment and experience as on scientific theory.

Role of Utilization in Rangeland Management

Rangeland planning involves setting resource objectives and prescribing management practices to meet those objectives. Monitoring is the collection and interpretation of data to document the implementation of the plan and progress, or lack of progress, toward meeting objectives. Re-planning, or adaptive management, occurs when acceptable progress is not occurring, objectives are changed, or conditions change that render the initial plan obsolete. Utilization is one of several tools that can be used in an adaptive management decision process. The following discussion is intended to describe the role of utilization within the context of rangeland management and decision making.

A grazing management plan describes the resource and other objectives to be achieved for the management unit. The plan outlines the practices (e.g. grazing management, physical improvements, monitoring, etc.) to be implemented in order to meet objectives. Whether or not the prescribed management will actually result in achieving objectives cannot be predicted with certainty because of specific site conditions, weather conditions or other factors. Therefore, it is necessary to collect site-specific data over time to assess whether the plan is working and, if not, to establish the reasons it is not working, and propose corrective action. Documentation by monitoring of progress toward management objectives as described in the management plan is sufficient to demonstrate compliance with the plan until the plan is revised. Monitoring may indicate movement towards the management objectives, movement away from the management objectives, or no change. A determination of "no change" is not necessarily negative because it may indicate that satisfactory conditions are being maintained. When monitoring indicates no change and current conditions are considered to be unsatisfactory, or when monitoring indicates a change away from management objectives, it must be determined whether the situation is due to current management and/or other factors (such as drought) in order to decide upon the needed management changes.

It is usually not feasible to collect monitoring data over the entire management unit, therefore, monitoring data are collected in key areas. Key areas are those portions of the management unit that are agreed upon by knowledgeable parties to be representative of the effects of grazing management on attainment of plan objectives on a larger scale.

Data are collected to document changes that occur over time in attributes (e.g. ground cover, plant species composition, wildlife populations, etc.) that are relevant to the objectives of the plan. Observed trends in relevant attributes can then be interpreted in relation to the desired objectives and to reach conclusions regarding cause of observed trends and possible changes needed in grazing management.

Utilization guidelines are intended to indicate a level of use or desired stocking rate to be achieved over a period of years. For example, nearly all of the studies used by Holechek and Galt (2000) to develop utilization guidelines encompass 10-year grazing trials. Utilization levels in these studies vary depending upon both growing conditions in a particular year as well as the sampling techniques used. Utilization can be mapped over an entire management unit or observed in key areas that reflect the effects of grazing in the whole management unit. Because of this variability such guidelines are not intended as inflexible limits to use within any given year that dictate when livestock should be moved from one pasture to another or removed from seasonal ranges. Livestock utilization at the end of the grazing year that consistently exceeds utilization guidelines over a significant part of the pasture over a period of several years can indicate the need to make management corrections, or re-evaluate the guidelines, before undesirable long-term trends are identified by monitoring.

Utilization can be an important factor in influencing changes in the soil, water, animal, and vegetation resources (Bureau of Land Management 1985; Western Coordinating Committees 40 and 55 1998). However, the impact of a specific intensity of use on a specific plant species or plant community is highly variable depending on species composition, season of use, frequency of use, and other factors. Utilization studies are helpful in identifying key and problem areas and in mapping grazing distribution

patterns. "In combination with actual use and climatic data, utilization measurements on key areas and utilization pattern mapping are useful for estimating proper stocking levels under current management" (Bureau of Land Management 1985). Seasonal utilization data (in other words, utilization measured before the growing season is complete) can be used as one indicator for moving livestock within an allotment along with due consideration of season, weather conditions, and the availability of forage and water in pastures scheduled for use during the same grazing season, but it should not be employed as the sole indicator or as a rigid guideline. In summary, utilization guidelines may be used with other information to make short-term management adjustments, but they are not management objectives. For this reason, and the complexities described in this paper, strict interpretation of utilization guidelines is not recommended for regulatory standards.

Sampling Variability and Basic Assumptions

As in all range vegetation sampling, quantitative utilization measurements are subject to a high degree of variability, which must be accounted for in data collection and interpretation. Weight-based methods of measuring utilization depend on clipping or estimating herbage standing crop in grazed/ungrazed or in before and after grazing comparisons. The difference between grazed and ungrazed production is assumed to be the amount removed due to grazing. However, depending on the precision of sampling, differences could be due in part to productivity differences among the plots clipped regardless of grazing. Therefore, the calculated utilization could have either a positive or negative bias due to sampling variability. This problem would be greater in sparser vegetation than in more uniform and productive areas, such as meadows and in areas of relatively light utilization (Bork and Werner 1999). The problem can be partly addressed by selecting plots paired for similarity in potential (i.e. site potential and vegetation) for comparisons rather than a strictly random design. It can also be helped by increasing plot size to include more within plot variation or by increasing number of plots, or both. These requirements greatly add to the time and effort required to achieve reasonable precision. In practice, it is unusual (and impractical) to locate more than one or two cages in a key area, so the "ungrazed" sample will have only a few plots, usually of small size. Even if a larger number of paired, grazed plots are selected, the error of estimation of utilization will be high unless vegetation is very uniform (Halstead, Howery and Ruyle 2000).

To increase precision, methods that involve measuring grazed and ungrazed plant heights are often employed in conjunction with weight-based methods. These methods, usually associated with grass species, must also have a sufficient number of both grazed and ungrazed plants to account for height variability. Ungrazed heights within a species are fairly uniform as long as site conditions are uniform, so a reasonable average can usually be attained with measurement of only 10-25 plants. The number of grazed plants required for a desired precision depends on the variability in height of grazed plants that in turn depends on the type of plant and the level of utilization. Variability in grazed heights would be expected to be least at very high levels of utilization. At low levels of utilization variability could be due to natural variation in plant height, which can be considerable, but would probably increase as utilization increases to moderate levels due to animal selectivity.

Both weight and height based methods also depend on a number of assumptions that are usually hard to verify. It is assumed that growth rates of both grazed and ungrazed plants are the same through the growing season. It is well-established that cages used to protect plants from grazing can affect growth, usually positively, by altering microclimate, addition of nutrients by birds perching on the cage, or other factors (Laycock in Western Coordinating Committee 40 and 55, 1998). Grazing can stimulate or slow growth compared to ungrazed plants, depending upon such items as precipitation following the grazing event or the stage of plant development in which the grazing event occurred. Utilization, as usually defined, generally assumes that regrowth after grazing is insignificant. However, regrowth after a grazing event may be substantial if grazing takes place early in the growing season. Utilization may be difficult to measure and interpret when regrowth is substantial after grazing during the current growing season because the evidence of grazing may be obscured. Interpretation of utilization data can also be complicated when plants are subject to repeated grazing during a grazing period, or when the rate of disappearance of ungrazed forage due to natural weathering is rapid because these situations make it difficult to quantify both the total production and the amount removed.

The height- weight method is based on the premise that growth form of grasses is sufficiently constant between years, seasons, and sites to allow the use of average height-weight tables with reasonable accuracy. (Cook et al. 1962). Cook et al. (1962) say Clark (1945) found estimated errors as great as 10-25% may occur because of differences in growth from one year to the next on the same site. They also state that Heady (1950) found variations from year to year, but differences among sites were greater than among years. Heady (1950) pointed out that much of this variation can be eliminated by using separate height-weight tables for different height classes, as is done in the utilization gage developed by the Forest Service. Schmutz (1978) concluded that although height growth varied among years and sites, the basic relationship of height to weight was similar. He stated there was usually as much variation within a site as between them, and thus, with a large sample size, this

variation was averaged out and a properly developed photo guide could be used on all sites in good and bad years.

The literature suggests significant bias and/or errors in estimating utilization by a number of methods if sample size is inadequate or basic assumptions do not hold. In practice, the basic assumptions are rarely verified. We conclude that, in the absence of statistical tests of sampling variability to quantify confidence limits on utilization estimates, the confidence limits should be assumed to be relatively large. At best, this means that differences in measured utilization levels of 5-10% (e.g. 30% utilization compared to 35 or 40%) or less should probably be interpreted as non-significant unless statistical separation is demonstrated.

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Time (Season) of Measurement

Utilization guidelines cannot be employed for seasonal utilization because there is no known consistent relationship between seasonal utilization estimates and utilization based on the entire growing season's forage production. To establish such a relationship would require that the amount of subsequent forage growth could be accurately predicted at any given time during the growing season. Information to make such predictions does not exist. For this reason seasonal utilization estimates are not reliable for grazing compliance decisions employing utilization guidelines based on end-of-season production.

Because utilization is defined as the percentage of the current year's forage production removed by grazing, trampling, or other factors such as insects (SRM 1989, Interagency Technical Reference 1999), utilization measurements require that the current annual production is estimated. This can only be done at the end of the growing season using weight-based methods or methods that assume a biomass relationship (e.g. height-weight methods). Peak standing crop of vegetation reaches a maximum at the end of the growing season. Measuring standing crop before the end of the growing season does not account for subsequent growth, and measuring it after the end of the growing season reflects the loss of standing material to weathering, decay, and small animals. With height-based methods, it may be possible to measure maximum ungrazed height for some time after the end of the growing season.

Estimates of use that are not based on total annual growth, regardless of the method used, have been called "relative utilization" (Frost, Smith and Ogden 1994) or "seasonal utilization" (Interagency Technical Reference 1999); the latter term will be used in this paper. Seasonal utilization is the percentage of the forage produced in the current growing season to date of measurement that is removed by grazing. This percentage is different from utilization because it does not account for subsequent growth of either the ungrazed or grazed plants. Seasonal utilization measured early in the growing season has no consistent relationship to utilization based on total production. As the growing season progresses, the difference between the two measurements is reduced because the time available for regrowth diminishes For example, Smith in Western Regional Committee 40 and 55, 1998 described a clipping study showing the following relationship between seasonal utilization and true utilization for Thurber needlegrass. *(See Table 1 below.)*

Clipping to one inch in the pre-boot stage removed 80% of the growth to that date, but this was only 17% of the total growth on that plant by end of season. Obviously, utilization based on end of season production increased until it was the same as seasonal utilization at the final date. Although clipped to the same levels in the following year, both seasonal and true utilization were not the same in each phonological stage because of better growing conditions late in the growing season in that year. This example illustrates how seasonal and true utilization differ and that there is no way to predict true utilization from seasonal utilization at any given date.

It is important for managers to be aware of use levels, residual vegetation and other grazing impacts during the period of use as well as utilization at the end of the growing season. However, if the grazing season corresponds to the growing season interpretation of seasonal utilization data is difficult because neither the rate of growth/regrowth nor the rate of utilization can be accurately predicted during the growing season. Only sufficient experience over time can provide enough information to the decision-maker concerning the appropriate level of seasonal utilization which will closely approximate the desired year-end utilization. Observations of utilization from the end of the growing season until the start of the next growing season, i.e. during the dormant season, assume no further growth and/or regrowth. Some rangelands (e.g. Southwestern U.S), have a bimodal rainfall pattern that may support both cool-season and warm-season plant growth. This situation complicates the definition of growing season and interpretation of both utilization and seasonal utilization data. It may require identification of two or more growing seasons with an appropriate suite of plants and utilization measurement schedules for each.

Table 1 Seasonal and true utilization (%) on Thurber needlegrass based on clipping to a one-inch stubble height at different phonological stages during one year.

Util/Growth Stage	Pre boot	Early boot	Late boot	Anthesis	Soft dough	Hard seed	Seed shatter
Seasonal	80	84	92	93	94	96	96
End of Season	17	27	48	53	71	64	96

Stubble height, or residual biomass, can be measured anytime of the year since there is no reference to total forage production. Stubble height estimates may be used instead of seasonal utilization measurements. However, interpretation of stubble heights measured during the growing season must be based on demonstrated relevance of observed stubble heights to the resource value and/or ecological process of interest.

Key Forage Species

The Society for Range Management (1989) defines key species as "a forage species whose use serves as an indicator to the degree of use of associated species, and because of its importance, must be considered in any management program." Therefore, for utilization estimates, a key species must be a forage species; hence the term "key forage species" has been adopted for this paper. Selection of key forage species should be tied directly to management plan objectives and should be appropriate to the primary grazing animal. Utilization guidelines for key forage species, plant species frequency, cover, precipitation and other plant community data should all be evaluated to determine if changes in current management practices are necessary.

A key forage species is usually a reasonably palatable and abundant species (or several species) upon which management decisions may be based. Measuring utilization on key forage species is based on the idea that use on key forage species will be indicative of the overall use of a management unit and the quantity of forage removed from the unit. For this reason, highly palatable forage plants, or highly unpalatable plants, are generally not selected as key forage species because use on these plants does not provide information on the overall use of the management unit. Necessary assumptions to support this concept are: (1) Utilization on the key forage species is assumed to have a definite and constant relationship to utilization on other species, either more or less palatable than the key forage species; and (2) Use on the key forage species will increase during the growing season in direct relation to the amount of AUMs utilized in the pasture (Smith 1965). Knowledge of these relationships is necessary in order to select appropriate key forage species and to maintain the presence of species considered to be "ice cream plants." Although often present in small proportions within the community, their importance must be recognized through management considerations. Key forage species are specific to kind of animal, season of use, and current vegetation composition (Vallentine 1990).

On ranges where the composition of desirable forage plants had been substantially reduced by improper grazing, drought, fire or other factors, the most desirable forage plants on a given ecological site may be sparse or missing. In such cases these plants do not meet the definition of key forage species because utilization on these species is not a good indicator of the amount of use on other forage species and is not related in a consistent way to the amount of grazing use that has occurred within a management unit. In this situation it may be necessary to select key forage species that are more abundant and less palatable than the most desirable and/or palatable species (Interagency Technical Reference, 1999, p.5) as a basis for monitoring grazing pressure, even though the management objective may be to increase the composition of desirable forage species that have been reduced due to past grazing or other factors. To achieve that objective, it first must be verified that the area in question does, in fact, have the potential to produce the desirable species in substantial amounts, e.g. by correct identification of ecological sites. Second, it must be recognized that consideration of season of use and/or frequency of use, as managed through the duration of time plants are exposed to grazing, rather than stocking rate, will likely be the most important management consideration to achieve improved populations of these desired forage species.

"Proper use" on a key forage species has traditionally been associated with eco-physiological responses of plants to grazing and is the level of utilization that should maintain or improve the growth and reproduction of the key forage species. Proper use of key species will also indicate that other species of similar or lower palatability to the grazing animal in question will also be used at non-injurious levels. The exception to this are so-called "ice cream" plants that are more palatable and/or more sensitive to grazing, but less abundant, than the key species. These species are often minor components of the vegetation. Because of their high palatability, reducing stocking rates may have little or no effect on their utilization, and thus, management efforts to maintain them depends on timing and length of the grazing period. Oftentimes, management of these plants can best be conducted by providing for appropriate recovery periods following grazing, and by grazing areas containing these plants when they are less palatable relative to other available forage.

Utilization on key forage species is not the same as average utilization on all species or on all forage species. When the key forage species is properly grazed, the level of utilization on other forage species will generally be the same or less than the key species. Also, some plants may not be grazed at all (i.e. they are not forage species for the animal and season concerned). The following example illustrates this point: *(Table 2)*

In this case, when the key species (A) is utilized at 50%, the other forage species, B and C are utilized at 30% and

Table 2. Hypothetical data indicating the relationship of utilization on key species to other forage and non-forage species.

Species	% Composition on Weight Basis(a)	% Utilization on Weight Basis (b)	Weighted % of Total Vegetation Utilization(c)*	% Composition of All Forage Plants(d)	Weighted % of Total Forage Utilization(e)*
A Key Species	30	50	15	50	25
B	20	30	6	33	10
C	10	10	1	17	2
D	15	0	0	0	0
E	25	0	0	0	0
TOTAL	100		22	100	37

10%, respectively. Species D and E, comprising 40% of the total vegetative production, are unused. The weighted average utilization of all plants is 22%, i.e. 78% of the plant production on the site is unused. The forage species (A, B, C) comprise 60% of the total plant production. Of the forage species, A makes up 50%, B is 33%, and C is 17%. The weighted average utilization on all forage species is about 37%. This illustrates the fact that when the key species is utilized properly, the average utilization on forage species is only 37% and the average utilization of all species is only 22%. These relationships change depending on the relative composition of the different species and the relative preference shown for different species by the grazing animal.

Utilization should only be averaged across forage species where several species have similar palatability resulting in similar levels of utilization on these species on a management unit over a period of years. Utilization may not be the same on each species in every locale or year, but, overall, there should not be a consistent pattern of significant difference in utilization among species if they are to be averaged. For example, on the Santa Rita Experimental Range in southern Arizona, researchers developed a regression model using the percentage of grazed, or ungrazed, plants to estimate utilization by weight on a combination of native perennial grasses (Roach, 1950). This empirical equation was developed for the specific vegetation types in the location and could not be used elsewhere without validation. All forage species on the site should probably be considered key forage species in cases where there are several species that contribute a major portion of the forage base. The preceding is an example of a site-specific study that was used to justify basing utilization on a combination of forage species. Several years record of similar utilization on several forage species would serve as justification for averaging use on several key species each year.

Selection of the key forage species must be appropriate to the diet and habitat selection patterns of the grazing animal that is consuming the forage. "It is important to recognize that key species for one type of animal may be different than for another type due to differences in food habits" (Holechek et al. 2004). Therefore, forage available for wildlife cannot be estimated using utilization on key forage species selected for livestock unless the forage preferences and grazing distribution are the same. Reaching desired levels of use on key forage species and key areas for livestock grazing does not indicate that limits of forage availability or habitat quality for wildlife have been reached unless the distribution and diet selection are very similar.

Key Areas

The Society for Range Management (1989) defines key area as "A relatively small portion of a range selected because of its location, use or grazing value as a monitoring point for grazing. Key areas should be located within a single ecological site or plant community, be responsive to management actions and be indicative of the ecological site or plant community they are intended to represent" (Interagency Technical Reference 1999).

The key area concept is based on the premise that no range of appreciable size will be grazed uniformly (Holechek, Pieper and Herbel, 1998). When key areas are "properly" used there may be substantial areas that are used more or less than the key areas, including some that will not be used at all. Thus utilization in key areas selected for cattle grazing may not accurately reflect availability of forage or cover for other animals that use different parts of the range including critical management areas. Use pattern mapping or documentation of small impact areas may be useful for addressing this issue.

Key areas should receive substantial use, but should not be areas of heavy concentration. Key areas should not be located near watering points, roads and trails or in bedgrounds and saddles. Relatively small areas within a pasture where animals concentrate use are not key areas because they do not indicate use on the forage base as a whole. These areas may or may not be critical management areas. A critical area is defined as "An area which should be treated with special

consideration because of inherent site factors, size, location, condition, values, or significant potential conflicts among uses" (Interagency Technical Reference 1999). "Critical areas are areas that should be evaluated separately from the remainder of a management unit because they contain special or unique values. Critical areas could include fragile watersheds, sage grouse nesting ground, riparian areas, areas of critical environmental concern, etc." (Interagency Technical Reference 1999). Criteria for interpretation of utilization data may be different for critical areas and key areas. Utilization guidelines applied to key areas may not be representative of use in critical areas. When appropriate and based on management objectives, critical management areas may limit use in surrounding areas. This is especially true if the critical management area can not be managed independently.

More than one key area may be selected and monitored within a pasture or other management unit depending on the size of the unit, number of ecological sites, and/or management objectives. In that case, all should be considered when making management decisions. Designating one key area among several selected in the pasture to be the only one used for decision purposes is not consistent with the key area concept or supported by the range profession. Each key area is selected because it is representative of use in a portion of the pasture. Utilization may vary among key areas in any given year due to differences in livestock distribution caused by weather, water availability, season of use, class of livestock, or other factors. The pattern may be different in other years. Therefore, selecting one key area receiving the heaviest use in the pasture should not limit grazing in the pasture in any given year. Rather, the general or average utilization in all key areas should be evaluated. If one key area consistently receives substantially heavier use than the others over several years, then it may be located in an inappropriate location (e.g. in a concentration area where use if not typical of any substantial part of the pasture). If, however, the location of the key area receiving consistently heavier use is found to be representative of use in a significant part of the pasture, this may indicate a distribution problem requiring some management change.

Guidelines for utilization of key forage species on key areas are not the same as average use guidelines across entire pastures such as those of Holechek (1988). Holechek's "utilization guidelines for different range types" are based on conclusions from numerous research studies conducted in different conditions. They are not site-specific and are only valid as a starting point for interpreting utilization. Managers must further refine and validate utilization guidelines so they are tailored to each particular situation. Values developed on a site-specific basis can be validated through trend monitoring and consideration of all factors contributing to conditions on the site over time. Holechek's recommendations refer to a range of utilization levels over an entire pasture or management unit, not utilization on key species in key areas. The range of values is given to allow for differences in topography, water distribution, season of use, type of livestock and other factors that may affect the distribution of grazing use within the management unit. Depending on these distribution factors a given level of utilization on key species in key areas will have a different relationship to average utilization over the entire unit, i.e. the amount of forage supplied by the management unit.

Because this point seems not to be well understood, the following needs to be emphasized. The percentage utilization of key forage species is higher than the percentage utilization of all herbage production of all species, because some of the associated species will be used less than the key species and some will not be used at all. The utilization on the key forage species is intended to be an index to overall use. The percentage utilization on key forage species in key areas is not the average utilization of key forage species across the entire unit unless grazing distribution is very uniform. Grazing distribution on rangelands usually results in relatively small areas receiving more use than the key areas and a relatively large area receiving less use than key areas or no use at all. Thus, the use level on key forage species in key areas is normally higher than the average use on key forage species across the entire management unit. The total percentage of utilization on current year's production on all species across the entire management unit is always less, and usually much less, than the percentage utilization on key forage species in key areas. The important point is that achieving "proper use" of key forage species in key areas for livestock does not mean that no forage remains for other kinds of animals with different diet preferences (i.e. key species) and different distribution patterns (i.e. key areas).

Utilization Guidelines and Range Condition

While it may be intuitively sensible, setting a different proper use level for different range condition classes or seral stages is not supported by research, at least within the bounds of conservative stocking levels currently recommended on public lands. Proper use is defined as "A degree of utilization of current year's growth which, if continued, will achieve management objectives and maintain or improve the long-term productivity of the site." (Society for Range Management 1989). That definition implies that proper use on poor condition rangelands will allow for improvement. Ruyle (2003), cited Crafts (1938) and Parker and Glendening (1942) as having established higher levels of permissible use on ranges in good condition than those in poor condition. However, that recommendation was made during a period when, according to Ruyle (2003) 50% use was considered "conservative" and utilization even on the Santa Rita Experimental Range in Arizona averaged considerably higher than that. These levels of utilization are not currently recommended even on ranges in good condition. There appears to be no scientific evidence that proper use levels of 30-50% on ranges in good condition should be reduced if the range condition is poor. Poor condition ranges

(depending on how range condition is defined) will likely support fewer AUMs than higher condition ranges before proper use levels are reached.

Shrub-Dominated or Annual Ranges

Most of the quantitative methods for measuring utilization have been developed for perennial grasses. However, there are many rangelands where shrubs and/or annuals comprise a major portion of the forage resource for both livestock and wildlife. Some examples include Desert Scrub, chaparral, annual grassland, and some formerly grassland areas invaded by shrubby species. In these situations the basic assumptions regarding proper use and the relationship between use on key forage species and total forage consumption may not hold, i.e. estimated utilization may not be well-correlated with the amount of forage used unless all forage classes are considered. Additionally, the usual methods to estimate use on herbaceous species may not be easily applied to browse utilization (Bonham 1989). There are techniques for measuring utilization on shrubs and annual plants. Interpreting utilization data where several different life forms, each with its own measurement method, are involved becomes difficult. The "Landscape Appearance Method" (Interagency Technical Reference 1999) is one of the few methods applicable to mixed life form ranges. However, it provides qualitative information that would be useful mainly for use pattern mapping, not quantitative measurement of utilization.

As described earlier, estimates of utilization on key forage species to indicate grazing intensity assume a constant relationship between use on key forage species and other species in the plant community. This assumption may be reasonable on ranges used in a limited grazing season or where most forage species have similar life forms. It breaks down when grazing occurs yearlong, or at least across different seasons, and the forage resource is comprised of diverse life forms and varying seasonal growth responses. Studies have shown that livestock diet selection varies markedly depending on the growth response of different categories of plants. For example, Smith, Ogden and Gomes (1993) observed drastic changes in cattle diet preference depending on season in southern Arizona. Cattle shifted their preference among cool-season annuals, shrubs, cacti and warm-season perennial grasses from month to month depending on availability and attractiveness of each category of plants. Clearly, in this case, the percentage utilization on a perennial grass key species would have to be considered in terms of the season of use and would not be well-correlated with total forage harvest by livestock. Other examples can be cited from areas where seasonal diets may focus on winter or summer annuals, cool or warm season shrubs, and cool or warm season grasses depending on seasonal precipitation. Such variability in diet preference greatly complicates the interpretation of utilization data.

Other ecological relationships may also be important and realistic management objectives should be developed to address various resource goals and objectives. Utilization of perennial grasses should not be the primary data used to determine stocking rates where a substantial amount of the forage is provided by annual plants and shrubs. In these cases, estimated utilization on perennial grasses is not likely correlated with the amount of forage used unless all forage classes are considered. In all situations management objectives must be realistic and clearly stated and utilization guidelines established consistent with objectives and resource potentials. For example, ranges that have been invaded by shrubs may have entered a different ecological state that cannot be reversed by grazing management alone. On such ranges it is unrealistic to base management solely on perennial grasses because the shrubs may contribute an important part of animal diets.

Relationship of Utilization to Ecological Processes and Resource Values

If utilization guidelines are to be used to indicate "proper use" relative to uses other than livestock grazing, i.e. other ecological processes or resource values, then there must be some demonstrated relationship between the levels of use as measured and the process or value of interest. For example, utilization on key forage species in key areas (selected for livestock) cannot be used to indicate adequate residual cover for prey species of raptors, unless a relationship between these two factors has been demonstrated.

Most utilization guidelines are based on research involving clipping of individual plants, or livestock grazing studies on plant communities. Clipping studies measure the effects of defoliation on individual plants, i.e. top growth, root growth, seed production, or total production. Grazing studies generally relate utilization to maintenance of plant species composition and productivity of the overall plant community, including indirect effects of grazing such as litter cover, trampling effects, or watershed effects. Clipping and grazing studies usually were conducted without analyzing the relationship with other resource values, therefore utilization guidelines based on such studies are only valid for the purposes for which they were developed, i.e. estimating the influence of livestock grazing on certain plant, soil and plant community attributes.

Utilization as Basis for Adjusting Livestock Management

"In the short term, utilization data are considered with actual use and climate data to determine resource use levels and to identify needed adjustments in management actions. These same data can be used in the short term as the basis for adjusting grazing use by agreement or grazing decision" (Interagency Technical Reference 1999). Utilization at the end of the grazing season has long been a tool to consider whether an increase or decrease of stocking would be desirable in the next grazing season. Long-term utilization

data, considered along with other monitoring data, should be used to adjust management practices to achieve land use plan objectives or land health standards (Interagency Technical Reference 1999).

Because plant growth varies from year to year depending on the weather, a constant stocking rate will result in utilization that is inversely related to forage production. Most research on arid and semi-arid rangelands in the western U.S. indicates that conservative stocking levels, based on long term pasture averages of 35% use of average total forage production (recommended utilization in higher rainfall areas may be greater) will maintain or improve vegetation condition where brush encroachment is not a problem (Holechek, Pieper and Herbel, 1998). It should be noted that this recommendation is a broad generalization based on averages over time, entire pastures and total forage production, concepts different than key areas and key species. It should also be noted that the recommendation of 35% use is intended only as a starting point in the absence of site-specific data, such as trend data compared to long-term utilization and actual use records.

Stocking rate studies are based on average stocking rate and the utilization over a period of years. Utilization in any given year may be substantially higher or lower under the same stocking level by pasture or allotment. As Holechek et al. (1999) describe in a review of stocking rate studies, "Desert forage plants can sustain about 40% use of annual herbage production. Use in the drought years approached 55-60% while use in the wet years was near 20-25%.

Recommendations derived from grazing studies are averages resulting from such variability and are intended to be met over the long term and not on a year to year basis."

Holechek and Galt (2000) go on to say, "…attainment of specific use levels is nearly impossible on a year-to-year basis due to variation in climate. Instead, we believe they should be a target across 5-10-year time periods."

If utilization levels consistently exceed desired levels, even during years of average or better forage production, a change in management practices may be warranted. For example, management changes may be needed if utilization guidelines are exceeded on over 30% of the pasture or allotment for two consecutive years or in any two years out of five (Holechek et al. 1998). This recommendation, while not directly supported by research, is a reasonable rule of thumb, but needs further refinement, especially for pastures used as part of a grazing rotation where use is rotated among seasons and years. If used in conjunction with utilization pattern mapping there may be an indication of a distribution problem that needs to be addressed. This would be especially true if the 30% of the pasture, where utilization guidelines are exceeded, provides the bulk of the forage actually utilized. This is often the case in mountainous terrain with a great diversity of topography and ecological sites.

Utilization measured at the end of the grazing season may provide an "early warning" that stocking rates or other management changes are required before resource damage is documented by long-term monitoring. Measuring utilization also gives some indication of the amount of needed adjustment, up or down, in stocking rates, that trend measurements do not provide. However, it is clear that utilization data must be interpreted with due consideration to effects of weather, actual stocking and reliability of utilization data before any change in management is suggested.

As stated above, utilization data have been used to calculate needed adjustment in stocking rates to attain "proper use" levels on rangelands. To do this, utilization measured at the end of the grazing season is compared to the desired level of utilization and actual stocking during the current year and stocking adjusted by the ratio of these two values. (Valentine 1947; Bureau of Land Management 1985). Seasonal utilization cannot be used for this purpose because no consistent determination of "desired" utilization is possible. For formula based on utilization of key species on key areas, see box below.

This procedure assumes that proper use in the key area will result in acceptable use over the entire management unit, except for relatively small concentration areas. If there are several key areas within a pasture or management unit the average utilization across the key areas should be used for this calculation, provided that the various key areas are all used at about the same rate over a period of years (as previously discussed under key areas above). If the key areas do not average out about the same over several years, then their locations should be re-evaluated to see if they meet the requirement that key areas should be representative of management on the entire management unit. Use of this formula provides an estimate of how many AUMs could have been carried on the unit in the current year to achieve proper stocking. It does not indicate whether that number will result in proper stocking the next grazing season or over a period of

Formula based on utilization of key species on key areas

Desired AUMs / Actual AUMs = Desired Utilization % / Actual Utilization %; or

Desired AUMs = Actual AUMs X Desired Utilization % / Actual Utilization %,

where desired utilization % is the level of utilization considered to be appropriate for achieving management objectives.

years. To make that interpretation requires consideration of the conditions of weather and other factors occurring during the current year compared to average conditions.

Another approach to estimating proper stocking rate using utilization data is to calculate a weighted average level of desired utilization over an entire pasture. (Valentine 1947; Anderson and Currier 1973; Bureau of Land Management 1985) This is accomplished by mapping use zones (use pattern mapping) and estimating utilization in each zone. The observed utilization in each zone is weighted either by the acres in the zone or the pounds of available forage in the zone to come up with a weighted average current utilization. The observed relative utilization in each zone can then be used to come up with a weighted average desired level of use for the pasture. These values are used in the formula above to calculate estimated increase or decrease in stocking to achieve desired use levels. Since use zones vary in a pasture from year to year, it is advisable to consider use levels over a series of years in arriving at proper use levels for each zone. Use pattern mapping is very useful for planning range improvements such as fencing and water development. Comparison of the expected increase in AUMs resulting from different combinations or locations of improvements can be obtained by adjusting the proper use levels to reflect anticipated changes in animal distribution.

Valentine (1947) stated that "the most dependable means of determining grazing capacity of range is through the use of actual stocking and forage utilization data…" This is probably true. However, it must be recognized that grazing capacity is highly dependent on many factors that vary seasonally, annually, or even in decades. Thus, estimates of grazing capacity (carrying capacity, proper stocking rates) are nothing more than general approximations that must be tempered with other information, experience and judgment.

Utilization as a Trigger for Moving Livestock

When utilization was first employed as a measure of grazing intensity, most ranges were used in a continuous season-long or year-long grazing system. In the past 20-30 years some type of rotational grazing has become the norm. The implementation of grazing systems led to changes and controversy in the way "utilization" has been employed for grazing management decisions.

Utilization guidelines are generally intended to indicate a level of use or desired stocking rate that would be achieved over a period of years. They are not intended as inflexible limits to use, in isolation from other data, within any given year to dictate when livestock should be moved from one pasture to another in a rotation or removed from seasonal ranges.

Decisions about moving livestock from one pasture to another, or about removing livestock from a grazing permit or lease, should not be based on rigid utilization guidelines. Such decisions should take into account the influences of weather and other factors on the entire management unit, including all categories of land ownership. Because most ranches in the western United States contain some mixture of private, State, and Federal lands, failure to use a coordinated, landscape level approach can often mean that decisions made by one agency only exacerbate conditions or thwart management objectives on other land ownership within the unit. Each ranch operation is unique and coordinating and collaborating amongst various land owners, ranchers, land management agencies, and others such as game and fish habitat biologists, can accommodate management objectives relevant to large landscapes and the diversity they encompass.

Seasonal use data, when evaluated with knowledge of climate patterns, current year's weather, previous years' actual utilization, historical impacts on the landscape, long-term trend data, and sufficient experience on the landscape to understand long-term vegetation responses to variable conditions provide the range manager with the ability to read the landscape and make the management decisions to provide for stewardship of the resources. Some adjustments to livestock management may be advisable during a particular grazing season. However, management adjustments should be primarily based on observation of consistent levels or patterns of utilization over a period of years.

There are some who maintain that "utilization" should be measured at the end of the grazing period, i.e. when livestock are moved out of a pasture. They claim that waiting to estimate use at the end of the growing season tends to obscure the impact of grazing due to regrowth. There is value to describing the level of use on a pasture at the time livestock are removed, so long as it is recognized that this use is "seasonal use", not utilization. However, the argument that grazing impact cannot be ascertained if measurement of utilization is deferred until the end of the growing season appears to lack understanding of the reason utilization is measured. Research and experience have shown that utilization of 30-50% based on total annual production, depending on whether it is defined on a key species/key area or range wide basis, will provide for continued productivity of the range. However, this level of utilization may result from grazing early in the growing season that produces "seasonal utilization" far in excess of this guideline. Obviously, the decision of whether a given pasture is "properly" grazed depends not on the "seasonal use" when it was grazed, but on the comparison of grazed/ungrazed production at the end of the growing season. Thus, a proper use guideline of 40% may be achieved by considerably higher "seasonal utilization" early in the growing season and by utilization of 40% based on season-long production.

Use Pattern Mapping/Cause and Effect

Utilization estimates can be employed to map use over a grazing allotment or pasture (Anderson and Currier, 1973). This process does not rely on quantitative estimates of utilization. Qualitative estimates of overall use in each zone

(e.g. heavy, moderate, light, none) based on professional judgment reinforced by clipping or other methods to train one's eye to current growth conditions can be used to indicate relative use rates in mapped portions of the management unit. Such information can be valuable in identifying areas where livestock use may be excessive, or where changes in management or investment in range developments can improve distribution. Use pattern maps may also identify areas of potential conflict of livestock grazing with other uses, and areas where such conflicts are likely to be minimized. Use pattern mapping is a valuable tool in rangeland management planning.

Long-term trend data on ground cover, vegetation composition and the like document changes in these attributes. However, without some idea of the cause of such changes, there is no reasonable basis for decisions about needed changes in management. Consistently high livestock use over large areas associated with unfavorable trends, especially when trends are static or positive in areas with low or zero livestock use, would give a basis for concluding that livestock grazing at high levels may be contributing to undesirable trends. Conversely, positive or negative trends that do not correspond to observed livestock utilization may indicate that timing and amount of precipitation rather than grazing is the driving force in the observed trends.

Conclusions

The Interagency Technical Reference (1999) states that "Residual measurements and utilization data can be used: (1) to identify use patterns, (2) to help establish cause-and-effect interpretations of range trend data, and (3) to aid in adjusting stocking rates when combined with other monitoring data." These uses of utilization are consistent with the scientific literature, experience of the range management profession, and our analysis in this paper. The following statements summarize our additional conclusions regarding the proper use and interpretation of utilization data.

1. Utilization is a useful tool in range management decision making, but utilization guidelines should not be used as management objectives.
2. Utilization, as defined by SRM and others, is not the same thing as "seasonal utilization" measured before the end of the growing season. Utilization guidelines cannot be used for seasonal utilization. Seasonal utilization cannot be used to establish "proper use" on key species using information derived from studies of proper use levels based on total growing season production. End-of-season utilization cannot be reliably predicted from seasonal use measurement.
3. Utilization is an indication only of livestock grazing pressure, and is not necessarily related to any other resource uses or values unless such relationships have been documented by research or experience.
4. Key areas for livestock grazing are areas selected to indicate the general level of livestock use over a management area. Utilization in key areas does not necessarily indicate impacts on other resource values or uses.
5. Setting a different proper use level for different range condition classes is not supported by research, at least within the bounds of conservative stocking levels currently recommended on public lands. There is no known basis for establishing different utilization guidelines for different classes of "range condition."
6. Utilization guidelines and estimation procedures applicable to grass ranges may be inapplicable or difficult to employ on ranges where much of the forage supply comes from shrubs and/or annuals.
7. Use of utilization to adjust stocking rates should be based on measurement of utilization made in the fall on ranges grazed during the growing season, and in the spring on winter or year-round ranges. Excess utilization over a considerable portion of the range over a period of several years may indicate a need to reduce stocking or make other management changes. Likewise, low levels of utilization over large areas and several years may indicate an opportunity to increase stocking or improve distribution.
8. Seasonal utilization was never intended for and should not be used as a rigid standard to trigger livestock moves or removal from grazing permits. Seasonal utilization should only be considered in making such decisions when combined with due consideration of season, weather conditions, and the availability of forage and water in pastures scheduled for use during the same grazing season. The primary use of utilization data for management adjustments is where consistent levels and patterns of utilization are observed over time.
9. Seasonal and yearly management adjustments should consider effect on the operation of the entire management unit, including all land ownerships. Coordination across land ownerships can enhance management of the landscape as a whole.
10. Both mapping of use zones and estimates of utilization to provide collateral information for long-term trend monitoring provide information that is very useful in rangeland management planning.

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