J. ENVIRONMENTAL SYSTEMS, Vol. 15(1), 1985-86

PREDICTING UTILIZATION OF FORAGE SPECIES AND DIET ON GREAT BASIN DESERT WINTER RANGE

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ABSTRACT

One of the principal mechanisms operating in any grazing management program is the differential utilization of forage species. An ability to predict this differential utilization pattern and diet, prior to the application of a grazing program, would allow more accurate prejudgment of the program's expected success. A predicting scheme is discussed, along with an actual application of this scheme to prediction of utilization of forage species and diet by sheep on Utah winter range.

INTRODUCTION

Considerable attention has been given through the years to the effects of utilization on range plants. The role of differential forage utilization by domestic livestock in causing floristic changes is widely recognized. Little attention, however, has been given to being able to predict these patterns of utilization among individual range plant species.

One notable exception has been the work of Hutchings and others in studying grazing by sheep on Utah winter range [1]. Certain fundamental patterns of utilization were observed in their studies. For example, their data

doi: 10.2190/FGA2-DYW8-9VYA-JP99
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suggested that the percent utilization of plant species varied with their relative production values; the utilization of a species tended to increase with a decrease in its relative production. Other factors that seemed to affect relative utilization were growth conditions for the herbage, floristic composition of the community, grazing intensity, and phenophase of the plants when grazed. Holmgren and Hutchings have discussed the responses of salt desert shrub communities to these utilization patterns [2].

In theory, if the utilization of each plant species in a range plant community were predictable, and if, in addition, the effects of such utilization were known for each plant species, then as regards floristic composition, a range manager would have more complete prior assurance of the expected success or lack of success of a proposed grazing program. Described in this article is a simple, hand-calculator method of predicting this differential pattern of utilization, hence diet, among range plant species by domestic livestock. The specific examples given herein are for sheep on Utah winter range, but the principles are applicable to other range types, other seasons of grazing, and to other classes of livestock or wildlife.

THE BASIC EQUATION AND ITS USE

The basic equation relating utilization of individual plant species to utilization of total forage is as follows:

$$U_a = U_t^{(RA_a^X)} \qquad (1)$$

where U_a is the utilization of species "a", U_t is utilization of total forage, RA_a is the relative abundance of species "a", and X is an empirical parameter.

An example substituting real numbers better demonstrates the equation's use. Consider a situation where species "a" constitutes 35 percent of the total available current annual forage production or yield, and where total community forage utilization is to be 45 percent of the total available current annual yield. The basic equation would then, after substitution, become:

$$U_a = .45^{(.35^X)} \qquad (2)$$

The "X" Parameter

The "X" is an empirically derived parameter that plays a critical role in the predicting scheme. Because of its importance, it will be considered here in detail.

For each of "n" forage species in a community there is an appropriate "X" value ($X_1, X_2, \ldots, X_n$). Basically, X is an indication of the relative palatability or nonpalatability of a plant species within a community. If X is positive, the species is favored in the community. If X is negative, the species is not favored.

It is helpful to consider its effect in the two equations above which allows it to effect a high level of predictability. On inspection, when X = 0, the utilization of species "a" will be identical to the utilization of total forage. This is because .35 raised to the power of 0 equals 1, and .45 raised to the power of 1 is equal to .45. Mathematically, when X is greater than 0, the utilization of species "a" will be greater than the value for the total community utilization, and when X is less than 0, the utilization of species "a" will be less than total community utilization. Smaller positive values for relative abundance tend to accentuate the effect of X, hence, a favored species tends to be taken to a greater extent, a fact noted in the field. The value of X, then, whether positive, or negative, is an absolute indication of whether species "a" is a preferred or a nonpreferred forage species in the community. The higher the X value for a given species, the more it is preferred in that community.

X is a relative value rather than an absolute. It indicates, in any given plant association, the relative utilization to be expected for a plant species. It is meaningless in a single-species plant community, which can be seen by substituting the value of 1.0 into the relative abundance term. When the relative abundance is 1.0, the species comprises 100 percent of the community, and the value of X has no effect on the result of the equation.

The value of X for any species can be viewed as anything from a single constant to a complex function of other variables. The X value can, for example, change as a function of total forage utilization. Shadscale *(Atriplex confertifolia)* has a morphology such that the first 20 percent of new growth is both palatable and readily available to the grazing animal. So long as total forage utilization for the community remains below about 20 percent, the X value for shadscale remains positive in most associations. The remainder of shadscale's growth, however, is protected by spines, and in spite of the fact that total community utilization may rise well above 20 percent, the utilization of shadscale usually does not. At this point, the X value for shadscale becomes negative.

Precipitation patterns have been shown to exert significant impact on the X parameter. Winterfat *(Ceratoides lanata)*, a highly palatable, low-growing plant, can become unavailable under deep snow, and the animals will switch to less palatable shrubs. Indian ricegrass *(Oryzopsis hymenoides)* experiences heavier utilization in years when late summar rains stimulate the growth of basal leaves and freshen up the herbage [1].

While the X value for any given species can be expressed as a complex function of many different factors, for most of the salt desert plant species in this study a substantial part of the variability in the value of X is accounted for as a function of only the total forage utilization in the community.

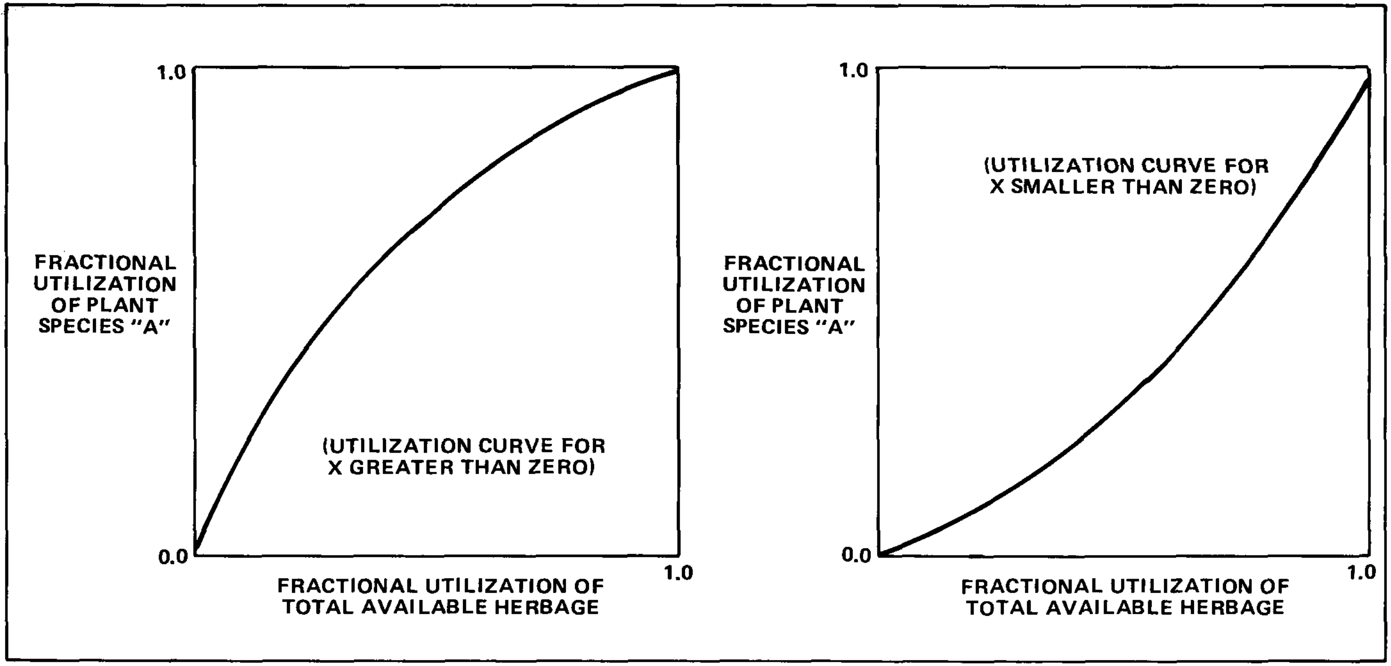

Figure 1. Utilization curves showing the effect of the "X" parameter in the predicting equation. When X is greater than zero, fractional utilization of the plant species is greater than utilization of the total available herbage. When X is less than zero, fractional utilization of the plant species is less than utilization of the total available herbage. When X is exactly zero, a straight diagonal line is produced and fractional utilization of the plant species is identical to utilization of the total available herbage. Thus, a positive X indicates a relatively heavily utilized forage species, and a negative X indicates a relatively lightly utilized species.

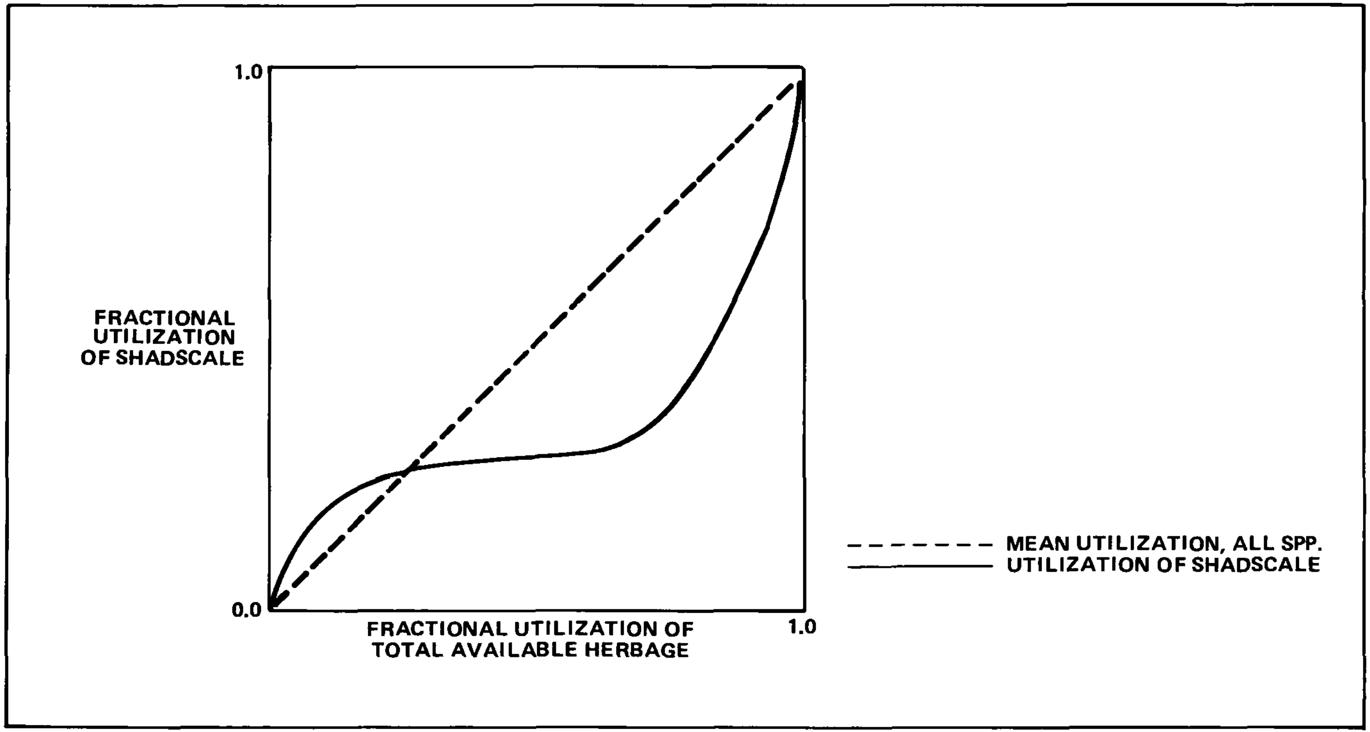

Figure 2. Representative utilization curve for shadscale. While total community utilization remains below about 20 percent, shadscale is frequently a preferred forage species. The remainder of the plant is protected by spines and little more is utilized until total community utilization becomes extremely high. Thus, the X parameter can be positive under light utilization, but become negative as utilization becomes heavier.

A TEST OF THE EQUATION SYSTEM

Method

One test of the equation system, using historical utilization data, will be discussed, although several tests of varying complexity have been run for a variety of grazing seasons and stocking levels.

The U.S. Forest Service has, since the mid-1930s, conducted long-term grazing experiments with sheep on Utah winter range similar to roughly 65 million acres of Intermountain rangeland. Hutchings and Stewart have discussed, in some detail, the results of the experiments as of 1953 [1]. Part of the information collected during this period was utilization of plant species by sheep under several experimental treatments covering a range of vegetational associations. The Forest Service graciously made these data available to the author for his use in the development of this predicting technique.

Six experimental pastures at the Desert Experimental Range, near Milford, Utah, provided that data for this test. They covered early, middle, and late-winter grazing as well as light, moderate and heavy grazing intensities. Table 1 shows the pastures, period grazed, and average utilization.

Parameter Development

Thirteen species or plant groups were studied in each pasture. For each species studied, the six pastures provided twenty-four utilization values, covering four separate years, under a multiplicity of plant associations. Each of the twenty-four utilization values was substituted along with appropriate relative abundance and total utilization vlaues into the predicting equation. The X values were obtained, in each instance, by solution of the basic equation. When all twenty-four X values were known, regression analysis of the effect of total utilization on X was made. This was a simple, linear regression of the

Table 1. Pastures Used to Develop the Predicting Equation and Parameters for the Desert Experimental Range, Annual Grazing Periods, and Average Annual Utilization of Total Forage Production

Pasture Number	*Annual Grazing Period*	*Average Utilization (Percent)*
6	January 4 to April 10	23
8	November 15 to January 3	39
9	January 4 to February 23	23
10	January 4 to April 10	17
11	January 4 to February 23	15
18	February 24 to April 10	48

type a + bx. Table 2 presents coefficients, derived from the regression analysis, for the determination of X values for the thirteen plant groups studied at the Desert Experimental Range.

An example will demonstrate the use of these coefficients in determining the utilization of shadscale. Assume, for this example, that shadscale comprises 35 percent of the total available current annual yield and total community utilization is to be 45 percent. The X value is calculated as follows:

$$X = .3500 - 2.0096\,(.45) = -0.554 \tag{3}$$

The equation predicting the utilization of shadscale then becomes:

$$\text{Utilization of shadscale} = .45^{(.35-0.554)} = .45^{1.79} = .24 \tag{4}$$

Thus, under these conditions, although the total community utilization is 45 percent, the utilization of shadscale is only 24 percent. It should be emphasized that the parameters in Table 2 are specific to grazing by sheep at the Desert Experimental Range. This area was chosen, however, as representative of some 43 million acres of salt-desert shrub community in the intermountain west.

Table 2. Regression-Derived Coefficients for Predicting the X Parameter for Each Species as a Function of Total Forage Utilization

Species	*Predicting Equation*
Atriplex confertifolia	.3500 − 2.0096 (U)[a]
Ceratoides lanata	.3162 + .3669 (U)
Artemisia spinescens	.2361 − .3616 (U)
Chrysothamnus spp.	−.2647 + .4655 (U)
Ephedra nevadensis	−.2875 + .2926 (U)
Other Shrubs	−.1710 + .1101 (U)
Hilaria jamesii	.0139 + .6573 (U)
Oryzopsis hymenoides	.1836 + 1.3289 (U)
Sporobolus spp.	−.6344 + 1.3935 (U)
Other Grasses	−.1393 + .0806 (U)
Salsola kali	−.1100 + .2603 (U)
Sphaeralcea grossulariaefolia	.2554 + .6930 (U)
Other Forbs	−.1083 + .3569 (U)

[a] (U) indicates the last term is multiplied by total community forage utilization.

The Testing Procedure

For each year and each pasture, preconditions for the graze were substituted into the equations, which were then solved for the species utilization. Only a hand calculator with a power function is required. In this manner, a predicted utilization value for each plant species, each pasture, and each year was obtained.

A check showed that in any pasture, for any year predicted, the first utilization values so obtained did not equate to the proper total community utilization value. That is, even though total community utilization of, for example, 45 percent was used in each species equation, the weighted sum of the individual utilization values obtained did not equal 45 percent. This variance arose, as it always will, as a result of differences in associational relationships among the species from those existing in the pastures from which parameters were developed. One could, for an extreme example, predict utilization for a community with just two plant species, even though the parameters for the two species were developed in much more complex communities. If both species are highly palatable, both may have X values greater than zero. In this case, the first utilization values obtained would result in excessive total utilization. To compensate for this error, all utilization figures are proportioned down or up to yield the proper total community utilization.

When all utilization predictions were made, diets were calculated. Each was then compared with its corresponding actually measured value. The comparisons follow in the next section.

RESULTS

Table 3 is a listing of the species or plant groups analyzed. For each species a Pearson's product-moment correlation coefficient (r) was calculated between the actually measured values and the predicted values for utilization and diet. For twenty-four observations, the average Pearson's r for utilization was .89 over all species, and for diet averaged .94 over all species.

DISCUSSION

Utilization values for some species or plant groups are predicted with much less accuracy than for others. Obviously, a category such as "other shrubs," can consist of a variety of things, some palatable, some not. That there was any predictability in these categories is surprising. Another problem lies, in part, with the data on which the parameters were estimated. In many pastures, rabbit brush (*Chrysothamnus* spp.), *Ephedra nevadensis, Salsola kali, Sphaeralcea grossulariaefolia,* and the "other" categories were all quite sparse, frequently not present at all. Small absolute errors in measurement introduce great relative variability into such estimates. In some instances, records of plant

Table 3. Pearson's Product-Moment Correlation Coefficients ("r") Between Predicted and Actually-Measured Utilization and Diet, and Ranges of Actual Relative Abundance, Actual Utilization, and Actual Percent of Diet, All Six Pastures, Four Years of Data Each

Species or Plant Group	*Percent Relative Abundance*	*Percent Actual Utilization*	*"r" Pred:Actual Utilization*	*Percent Actual Diet*	*"r" Pred:Actual Diet*
Atriplex confertifolia	14 to 47%	7 to 32%	.67	12 to 58%	.73
Ceratoides lanata	0 to 43%	50 to 91%	.70	0 to 56%	.99
Artemisia spinescens	1 to 6%	11 to 76%	.19	0 to 12%	.90
Chrysothamnus spp.	0 to 15%	0 to 70%	.56	0 to 8%	.79
Ephedra nevadensis	0 to 20%	2 to 39%	.39	0 to 7%	.95
Other Shrubs	1 to 15%	0 to 81%	.56	0 to 12%	.13
Hilaria jamesii	3 to 20%	5 to 92%	.84	3 to 32%	.84
Oryzopsis hymenoides	2 to 18%	43 to 100%	.78	4 to 48%	.96
Sporobolus spp.	4 to 50%	0 to 69%	.88	1 to 31%	.72
Other Grasses	0 to 6%	0 to 45%	.57	0 to 2%	.32
Salsola kali	0 to 31%	0 to 43%	.81	0 to 36%	.99+
Sphaeralcea grossulariaefolia	0 to 3%	57 to 98%	.39	0 to 11%	.99
Other Forbs	0 to 13%	0 to 82%	.48	0 to 6%	.10

growth showed certain species to be absent from the pastures; nonetheless, utilization values were recorded. Because the author wanted not to manipulate the data in any way, such inconsistencies could not be excluded. Fortunately, the paucity of these species renders such errors quite tolerable. If the presence of a species is so small as to be almost unmeasurable, one probably doesn't care whether it is utilized at a rate of 100 percent or 0 percent. The impact on diet is, of course, negligible.

Astonishingly better results are obtained when the X parameter development for each species also includes growing period precipitation. Unfortunately, this takes the analysis out of the realm of hand computation and renders it rather more cumbersome.

Other unpublished tests show that the equation system works well for other pastures on the Desert Experimental Range. Obviously, however, for remote locations, these parameters may be inappropriate. Ideally, parameters should be developed on a site-specific basis. This is not practical in many cases, however, in which case these parameters or, preferably, others developed for a nearby site with similar plant community can be used as the best available approximation in predicting utilization and diet.

ACKNOWLEDGMENT

The author wishes to thank Dr. James Blaisdell, Dr. Neil Frischknecht, and Mr. Ralph Holmgren of the Intermountain Forest and Range Experiment Station for making data available for this analysis. Particular thanks are due Mr. Holmgren for his assistance in interpreting and explaining the data and for providing many ideas that contributed directly to this work.

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