Determining Common Use Grazing Capacities by Application of the Key Species Concept[1]

ARTHUR D. SMITH

Professor and Game Biologist, Utah State University and Utah State Department of Fish and Game, respectively, Logan.

Highlight

Correct substitution rates of one grazing animal for another under common use take place at uniform rates, being governed at any point by the utilization standard of some single species. The capacity under common use may be greater than that realized with the less suited animal alone, or greater than either animal alone, depending upon the particular combination of animal numbers and the particular range.

Western ranges produce forage for more than one kind of animal—usually cattle, sheep and big game animals. Common-use grazing—the concurrent use of the range by more than one kind of animal—has been advocated as a means of maximizing range production. It is widely believed that such use promotes: (1) better distribution of animals and more efficient use of a range, and (2) harvesting of more of the available plant species.

Little research has been conducted on the common-use problem despite its importance. This report considers how grazing capacity is influenced by common use disregarding distributional advantages. It is partly theoretical and partly based on data collected over several years on the foraging habits and plant preferences of mule deer and livestock.

Standing (1938) first presented the key species concept and outlined the characteristics of key species and their use in range administration. Stoddart and Smith (1943) presented hypothetical figures to demonstrate an increase in grazing capacity under common use. Data by Julander and Robinette (1950) showed that deer and cattle together occupied all parts of a range better than did either animal alone. Data on the utilization of plants by sheep and cattle (Cook, 1954) purported to show a gain in carrying capacity under common use. Hopkin (1954) analyzed Cook's data and drew a substitution curve for common use between sheep and cattle as a means of determining the combinations of animal numbers that could give maximum returns.

The basic ideas elaborated here were first presented by the author at the Western Association of Game and Fish Commissioners in 1962, but the material was not published. This paper is an extension of the views presented there.

Methods for Arriving at Common Use Grazing Capacities

The usual procedure has been to determine proper use figures for each plant species for each of the two kinds of animals under consideration. The larger of each pair of forage factors obtained by multiplying the proper use figure by the species composition are then added to arrive at the forage factor applicable under common use. The data presented by Cook (1954) were treated in this way (Table 1). The major species only are shown. They illustrate the customary procedure and the one being proposed. Omitting the minor species changes the values but not the principles involved.

In this plant association (Table 1), bearded wheatgrass *(Agropyron subsecundum)* is the logical indicator species for common use by sheep and cattle by reason of degree of use and volume. It cannot be fully used by both animals to the extent indicated since this would give a combined use of 79 percent, a level far exceeding proper use. The numbers of one or all of the animals must be reduced to bring the combined use of this species within acceptable limits.

Several combinations of animal numbers are possible, but, for simplicity, assume sheep are stocked at a level to result in the utilization figure shown (24 percent) and further assume that 55 percent is the maximum permissible use on bearded wheatgrass. Then, under common use, only 31 percent of the production of this species is available for cattle. This amounts to 56 percent of the amount eaten when cattle are grazed alone (31/55 = 56 percent). If the forage factors for the other species are likewise adjusted to 56 percent of the values when cattle are grazed alone, thus assuring that wheatgrass is properly used, the resultant cattle factors are as listed in the last column. These represent the amounts of forage available for cattle under common use without overuse of wheatgrass. The combined forage factor for common use is 0.1842 (total for sheep) plus 0.1899 (new total for cattle) or 0.3741. Adding the footnoted values to arrive at the combined value results in a factor of 0.4002, a figure that is 11 percent too large.

This discrepancy is the result of the assumption that reducing the numbers of one of the grazing animals changes the utilization only of the preferred species for which the animals compete. For example, the forage factor of 0.0094 for snowberry *(Symphoricarpos vaccinioides)* for sheep is larger than the cattle

[1] *The original data were collected under Pittman-Robertson Project W-105-R.*

Table 1. Forage factors reported by Cook (1954) reanalyzed to illustrate indicator species concept.

Species	Composition (%)	Utilization Sheep (%)	Utilization Cattle (%)	Forage factor Sheep	Forage factor Cattle	Cattle factors[1]
Agropyron subsecundum	11.2	24	55	0.0269	0.0616[2]	0.0345
Bromus carinatus	22.5	15	35	0.0337	0.0787[2]	0.0441
Elymus glaucus	39.4	9	46	0.0355	0.1812[2]	0.1015
Lathyrus leucanthus	5.9	45	20	0.0265[2]	0.0118	0.0066
Thalictrum fendleri[3]	11.6	45	5	0.0522[2]	0.0058	0.0032
Symphoricarpos vaccinioides	3.9	24	0	0.0094[2]	0	0
Totals				0.1842	0.3391	0.1899

[1] Based on use of unused Agropyron (56%).
[2] Values proposed by Cook to apply under common use.
[3] Forage factors adjusted to correct error in original data.

factor (Table 1). The sheep factor therefore retains the value of 0.0094 irrespective of the combination of animal numbers assumed and despite the fact it was not used by cattle.

Key Species Concept in Practice

Despite the long standing acceptance of the key species concept, the manner in which it may be applied has not been analyzed in detail. Standing (1938) lists the following characteristics of a key species: high palatability, reasonable withstandibility to grazing and to competition, reasonably abundant, nutritious, and producing a reasonable volume of growth. The one or few species on a range that meet these criteria provide the basis for decisions regarding the level of utilization and proper stocking for the range as a whole.

The existence of a unique relationship between the percentage utilization of the key species and the use of the other important forage species is implicit in the key species concept. The key species must be gradually and continually used throughout the grazing season with no sudden or marked changes in utilization.

Figure 1 illustrates acceptable and unacceptable characteristics for a key species. Species A is not suitable since it is removed by grazing well before the forage in general is being appreciably used. Species C is not used until late in the season after other species have been heavily grazed. Species B is used continually throughout the entire grazing period and provides the unique index demanded, thus qualifying as the key species.

Livestock Grazing Habits in Relation to Key Species.—Notwithstanding the theoretical relationship shown in Figure 1, animals apparently consume the major forage species from a given mixture in somewhat constant proportions throughout the

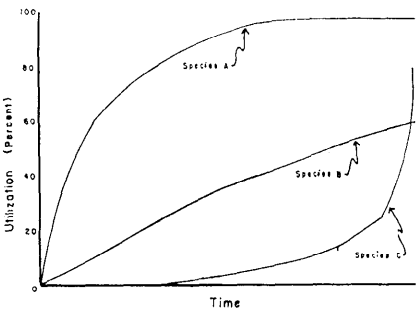

FIGURE 1. Theoretical cumulative utilization of three plant species during the grazing season.

permissible range of utilization. Thus, if twice as much plant D is taken as plant E, and both are important forage species, this relationship will differ little irrespective of the level of use. Utilization data for bitterbrush *(Purshia tridentata)* and cliffrose *(Cowania stansburiana)* (Smith and Urness, 1962) seem to confirm this. Further, Hurd and Pearse (1944) give utilization figures for eight reseeded grasses which show proportional use of the eight species up to about 60 percent, a reasonable limit of use for key species.

Whether or not this proportionately is maintained throughout the grazing season, however, at any time during the grazing season on a given range, the degree of use of individual species by a particular kind of animal is proportional to the number of animals present. This is the basis for the approach proposed below. In the analyses, three assumptions are made:

1. Sufficient forage of the major species is available within the limits of permissible use so that animals are not compelled to adjust their normal forage preference to offset lack of forage.
2. The common use of a range by two kinds of animals does not alter the preference of either animal for the major forage species.
3. The use factors for an animal are proportional to its population on the range.

These conditions may not be precisely met under all conditions, but the small deviations which might occasionally occur would only slightly influence the computed grazing capacities.

A Hypothetical Illustration

In its simplest form the concept proposed can be illustrated by hypothetical figures wherein three plant species make up the forage crop. One of the three is eaten by both animals. The other two are specific, one to each kind of animal. Animal 1, when alone, is assumed to eat two units of plant A and two units of plant B for a total of four. Animal 2, when alone, eats two units of plant B and two of plant C, likewise a total of four. Now if equal numbers of both animals are placed on the area and utilization of plant B is allowed to continue until two units have been removed, each animal will have consumed one unit of plant B plus an additional unit of the species it alone uses. The total forage crop now is made up of one unit of plant A, two units of plant B, and one unit of plant C, or again a total of four units. These relationships are:

	Plant species A	B	C	Total
Grazing capacity				
Animal 1	2	2		4
Animal 2		2	2	4
Common use	1	2	1	4

Under the conditions of this illustration, no additional grazing capacity results from common use; since, for each unit of species B consumed, each animal consumes equal amounts of secondary species. Under actual conditions this situation is not likely to exist. It is more probable that plants other than the key species would provide different amounts of the respective diets of the two animals. The greatest grazing capacity would be obtained wherein the key species made up the smallest percentage of the animal diet. Thus, if the key species constitutes 10 percent of the diet, the total grazing capacity of the range is *10 x the capacity provided by the key species.* If the key species constitutes 50 percent of the diet, the total grazing capacity is only *2 x the capacity provided by the key species.*

Application Using Actual Data

Data collected near Logan, Utah, on the use of plants by deer and sheep can be used to test the proposed procedure (Table 2). The five species shown were eaten readily and, except for rose (*Rosa* sp.), made up appreciable parts of the forage crop. The other species involved were present in insignificant amounts, were lightly eaten, or were unimportant to one kind of animal.

On the basis of utilization alone, rose might appear to be the key species. But, since it is present in but small amounts, inefficient use of the range would result if it were selected as a use indicator.

The data in the deer-only column of Table 3 were calculated from Table 2 by adjusting the utilization of serviceberry (*Amelanchier alnifolia*) to 60 percent, an increase of 20 percent, and then adjusting the deer-use figures of the other species upward by the same percentage. The 60 percent figure was selected as proper use because of convenience and in order to provide more points to plot. At this level of use by deer, no forage is available for sheep. If the amount of forage allotted to deer is reduced in successive 5 percent decrements and the forage thus released is assigned to sheep, we may determine the grazing capacity with any combination of animal numbers while remaining within the limits of permissible use. The sheep factors in each combination were calculated as in the last column of Table 1. The same procedure was then followed beginning with complete use by sheep and allotting successively greater amounts of forage to deer but using aster (*Aster chilensis*) as the key plant, since it was the one most palatable to sheep.

Interesting relationships are revealed when these data are plotted (Figure 2). When the use of serviceberry is 40 percent by deer and 20 percent by sheep, the combined use of aster reaches 64 percent, more than the arbitrary limit of 60 percent judged to be full use. Similarly, when deer are exchanged for sheep and the use of aster is 50 and 10 percent for sheep and deer respectively, the combined use of serviceberry is 58 percent, a point just short of maximum use. The point of intersection of the two substitution curves marks the combinations of deer and sheep that will give maximum grazing capacity.

Under certain circumstances common use results in no increased grazing capacity, unless the least suited animal is using the area at the outset. Maximum capacity can be attained only under single use with the animal best adapted to the forage. An example of this situation involving deer and cattle is shown in

Table 2. Utilization and percent of diets of major forage species for deer (D) and sheep (S) on study area in Logan Canyon, Utah.

Species	Composition of vegetation (%)	Utilization (%) D.	Utilization (%) S.	Combined use without adjustment (%)	Importance in diet (%) D.	Importance in diet (%) S.
Amelanchier alnifolia	4	50	18	68	16	6
Purshia tridentata	5	35	14	49	14	6
Prunus melanocarpa	4	33	28	61	9	10
Rosa sp.	1[1]	48	44	92	2	1
Aster chilensis	3	12	49	61	3	13

[1] Less than 1.

Table 3. Calculated grazing capacities of a range for selected combinations of deer and sheep with two key species.

Stock	*Amelanchier alnifolia* Util.	F.F.[1]	*Purshia tridentata* Util.	F.F.	*Prunus melanocarpa* Util.	F.F.	*Rosa* sp. Util.	F.F.	*Aster chilensis* Util.	F.F.	Total Combined Forage Factor
					Amelanchier key species						
Deer	60	0.0240	42	0.0210	40	0.0160	58	0.0058	14	0.0042	0.0710
Deer	55	0.0220	39	0.0195	36	0.0144	53	0.0053	13	0.0039	0.0775
Sheep	5	0.0020	4	0.0019	8	0.0031	12	0.0012	14	0.0042	
Deer	50	0.0200	35	0.0175	33	0.0132	48	0.0048	12	0.0036	0.0838
Sheep	10	0.0040	8	0.0039	15	0.0062	24	0.0024	27	0.0082	
Deer	45	0.0180	32	0.0158	30	0.0119	43	0.0043	11	0.0032	0.0901
Sheep	15	0.0060	12	0.0058	23	0.0092	37	0.0036	41	0.0123	
Deer	40	0.0160	28	0.0140	26	0.0104	38	0.0038	10	0.0029	0.1021
Sheep	20	0.0080	16	0.0080	31	0.0124	49	0.0049	54	0.0162	
					Aster key species						
Sheep	22	0.0088	17	0.0085	34	0.0136	54	0.0054	60	0.0180	0.0543
Sheep	20	0.0080	16	0.0080	31	0.0124	49	0.0049	55	0.0165	0.0748
Deer	21	0.0084	15	0.0075	14	0.0056	20	0.0020	5	0.0015	
Sheep	18	0.0072	14	0.0070	29	0.0116	45	0.0045	50	0.0150	0.0931
Deer	40	0.0160	28	0.0140	27	0.0108	40	0.0040	10	0.0030	

[1] Util. = utilization; F.F. = forage factor

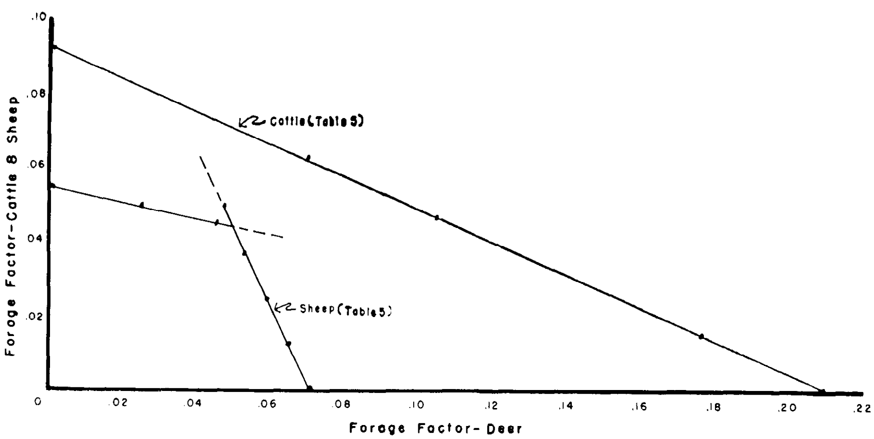

FIGURE 2. Substitution curves between mule deer and cattle near Fillmore, Utah, and mule deer and sheep near Logan, Utah.

Table 4 and the data are plotted in the upper line of Figure 2.

In this case, bitterbrush is the key species for both deer and cattle and remains so at all combinations of animal numbers. Although cliffrose is eaten more readily than is bitterbrush, it is present in such small amounts that it cannot be used as a key species. Since bitterbrush makes up a smaller percent of the diet of deer on this range than it does that of cattle, maximum grazing capacity is attained by allocating all the forage to deer. Adding cattle in place of deer reduces the amount of forage that can be harvested.

Hopkin's (1954: 174) diagram is similar to the sheep-deer data plotted in Figure 2 but includes a rounded curve. Although his data showed straight line substitution curves, he concluded that there was "nothing in the logic of range management or economics that supports the hypothesis that the marginal rate of substitution" is represented by straight lines which change abruptly. The data here presented demonstrate that this abrupt change from one uniform substitution ratio to another is in accord with the facts and the one to be expected.

Other Situations Possible.—The other theoretically possible situations, besides the two presented in Figure 2, are shown in Figure 3. Grazing capacity for animal A is indicated along the Y axis, and that for animal B along the X axis. Line A_1 B indicates the line of equal substitution between animal B and A. The range represented by this line is of equal productivity for either animal, and any combination of animals selected on this line provides the same grazing capacity within the limits of proper stocking. This situation could exist only when the forage preferences of animals A and B were identical, or when a key species common to both animals formed the same percent of the diet of each animal, i.e. when the associ-

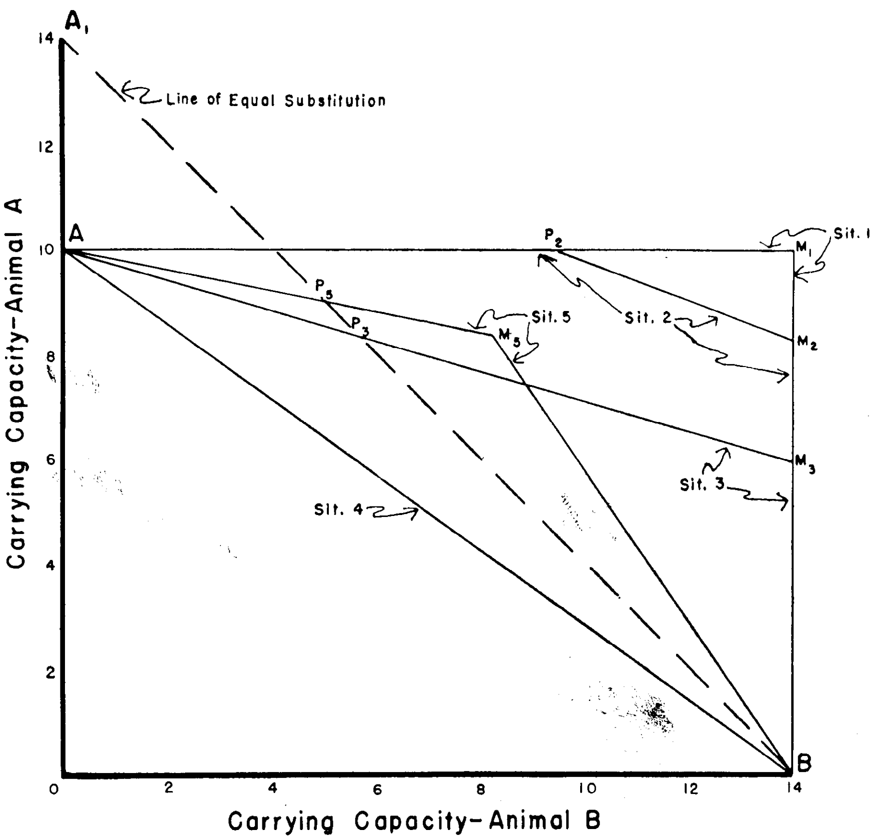

FIGURE 3. Theoretical substitution curves under five different situations.

ated species provided equal fractions of the diet to each kind of animal. It serves here as a point of reference.

Most ranges, however, will have greater capacity for one animal than for another. Point A shows the grazing capacity under single use for one animal and point B the capacity for another. These capacities are unequal, the most probable situation.

Each animal under situation 1 has a different key species and M_1 defines the point of maximum use of both animals since the individual carrying capacities are additive and non-competitive. The theoretical grazing capacity would be 10 for animal A, 14 for animal B, and 24 for common use. This situation is possible, but it is unlikely that no plant species will become the focus of competition at some level of stocking or combination of animals so long as we deal with common domestic and big game animals.

Situation 2 is illustrated by the lines A P_2 M_2 B. Each animal has its own key species when it grazes alone. Up to a certain point, either animal may be added to a range fully stocked by the other without competition, and the situation is initially like that of situation 1. At points P_2 and M_2, however, the combined use of a third key plant species becomes critical. The substitution line P_2 and M_2 then applies and maximum capacity is obtained at the combination shown by point M_2.

Situation 3 is one in which the key species, when animal A is grazed separately, is also grazed by animal B; hence, this key species is also the common-use key species. Conversely, the key species when animal B is grazed separately is not used by animal A. A certain number of animal A may be added to a range fully stocked by animal B without reducing the numbers of animal B (B M_3). On the other hand, adding numbers of animal B to a range fully stocked by animal A necessitates a reduction in the numbers of animal A since they must share a common key species.

With respect to situation 3, three possibilities exist. The one diagrammed shows animal A being added to B (B M_3) without competition. It may very well be the converse, i.e. that animal B could be added to a range fully stocked with A to a certain point without competition. Should the point (M_3) lie to the left of the line A_1 B, no combination of animals would result in greater capacity than is provided animal B alone. Should it lie on the line A M_1 to the right of A_1 B, the capacity under common use would in all cases exceed that of A alone but only at certain combinations would it exceed that of B alone.

Situation 4 is shown by the line A B, and grazing capacity can be maximized only by single use with animal B. The validity of this situation has already been demonstrated by the data of Table 4.

Situation 5 has also been previously discussed and is shown by the data in Table 2. Each animal has a distinct key species but each of these is also used by both animals. Under common use one key species exists from A to M_5, another from M_5 to B. Maximum capacity is attained at M_5, but again any combination of animals expressed by line A P_5 provides less grazing capacity than is realized by animal B alone.

The following generalizations can be made with respect to grazing capacities under common use. In any situation where a single unbroken substitution line is appropriate, single use is as efficient as, or more efficient than common use. In the relationship A_1 B any combination of animals which achieves full but proper use of the forage provides equal grazing capacity whether one or two animals be present. When, as in the straight line A B, there is greater capacity for one animal than for another, single-use grazing with animal B only will maximize forage production.

When two substitution ratios apply, as in situations 1, 2, 3, and 5, greater capacity *may* under certain circumstances be obtained by common use. If the angle, as at M_5, lies above (to the right) of line A_1 B, greater capacity can be achieved by common use than with either animal alone. However, this is only true for those combinations of animals above line A_1 B. For any combination of animal numbers indicated by the portion of the substitution lines below line A_1 B (AP_5) there is less capacity under common use than can be obtained by animal B alone. Any combination indicated by line AP_5

Table 4. Utilization by deer and cattle on a deer winter range near Fillmore, Utah, used by cattle spring and fall and calculated forage factors under common use.

	Deer only		Common Use Deer		Common Use Cows	
	Util.	F.F.[1]	Util.	F.F.	Util.	F.F.
Artemisia tridentata	32	0.1472	27	0.1242	1	0.0046
Purshia tridentata	60	0.0540	50	0.0450	10	0.0090
Cowania stansburiana	85	0.0085	71	0.0071	20	0.0020
Total Forage Factor		0.2097		0.1763		0.0156
Combined Total		0.2097			0.1919	

	Deer		Cows		Deer		Cows		Cows only	
	Util.	F.F.	Util.	F.F.	Util.	F.F.	Util.	F.F.	Util.	F.F.
Artemisia tridentata	16	0.0736	3	0.0138	11	0.0492	4	0.0184	6	0.0276
Purshia tridentata	30	0.0270	30	0.0270	20	0.0180	40	0.0360	60	0.0540
Cowania stansburiana	42	0.0042	50	0.0058	50	0.0050	50	0.0050	100	0.0276
Total Forage Factor		0.1048		0.0466		0.0722		0.0594		0.0916
Combined Total			0.1514				0.1316			0.0916

[1] Util. = utilization; F.F. = forage factor.

or AP_3, although inferior to grazing with animal B alone, gives greater capacity than can be realized with animal A. One must, therefore, identify the situation he is confronting before evaluating the efficiency of common use as compared to single use. Moreover, after the situation has been identified, consideration must be given to allocating the resource to the two animals in the proportions which will maximize grazing capacity.

Summary

Correct substitution rates of one grazing animal for another under common use are uniform, being governed at any point by the utilization standard of some single species. This key species may vary at different levels of animal combinations, thus changing the rate of substitution to another but still constant rate.

Under certain conditions, common use can add capacity in one direction only, e.g. when the animal to which the range is less suited is substituted for the other. In this case the best suited animal alone provides maximum grazing capacity.

The capacity under common use may be greater than that realized with the less suited animal alone, or greater than either animal alone, depending upon the particular combination of animal numbers that are present and the particular range.

No blanket statement may be made that common use increases grazing capacity. Each situation must be determined independently upon the basis of animal preferences and the forage present.

Administrative problems and social objectives, which were not considered here, may justify allocations of range resources on other bases than grazing capacity.

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