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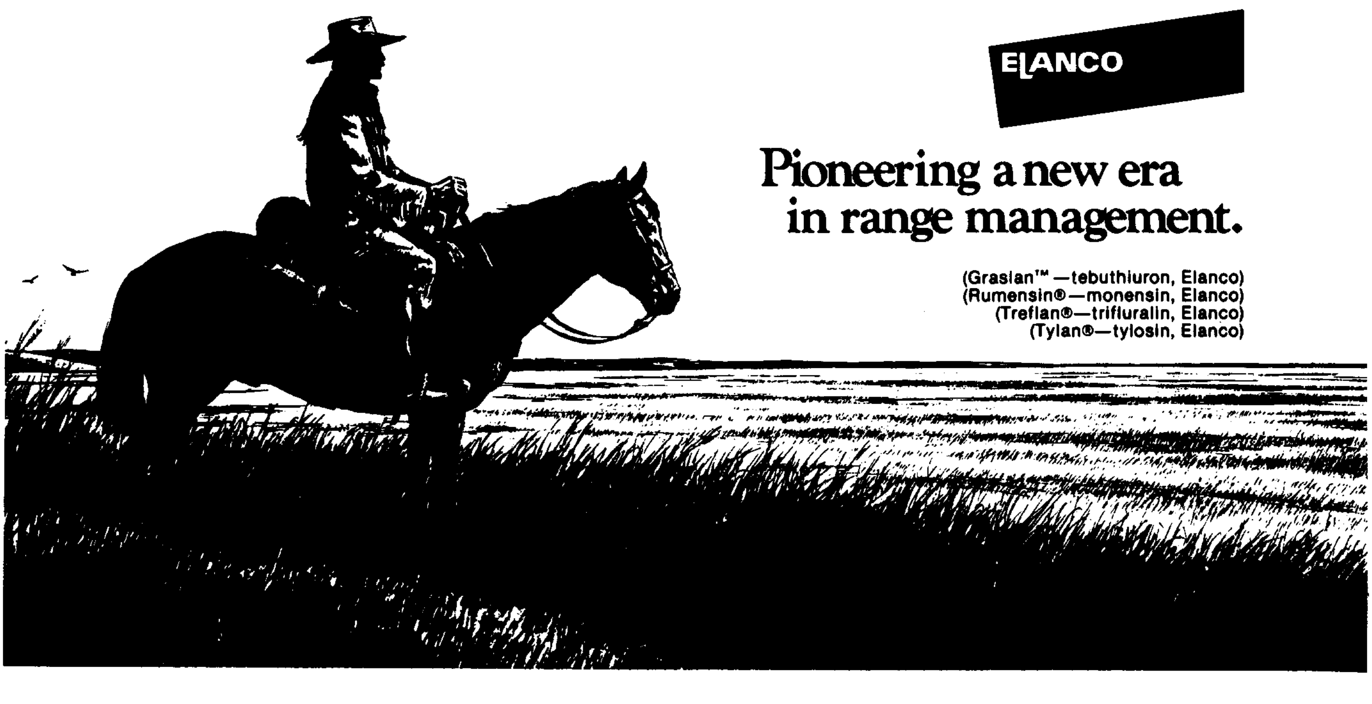

SOCIETY FOR RANGE MANAGEMENT

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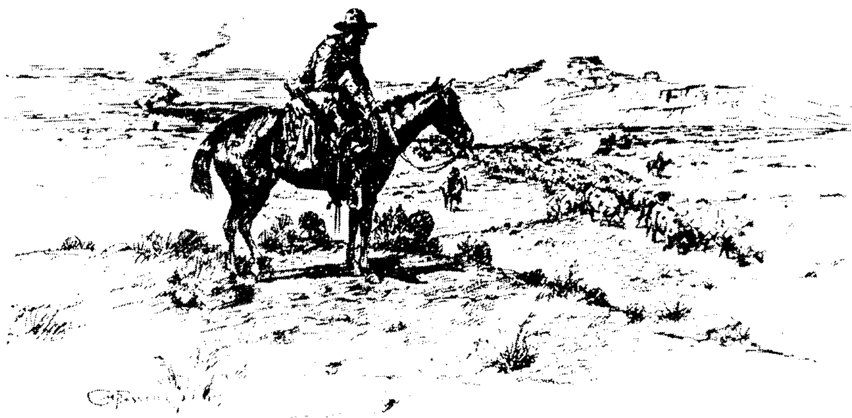

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BOOK REVIEWS

Concepts and Factors Applicable to the Measurement of Range Condition

A.D. WILSON AND G.J. TUPPER

Abstract

The concept of range condition is reanalysed in terms of the nature of changes in land and vegetation and the purpose of measurement. A new framework is outlined which presents range condition as an overall concept based on change in the value of land attributes, relative to their potential value. These attributes include factors such as the composition and quantity of the vegetation, the stability of the soil and the productivity of the land in terms of animals, water yield, or amenity value.

On this basis, indices of change in each attribute may be constructed from vegetation measurements. This will include separate indices of soil stability, animal productivity, and vegetation change (flora conservation), which may or may not be correlated with one another. Range condition cannot be defined by one of these attributes alone, so that the separation of ecological and productivity-based methods is artificial. Overall the importance of soil stability is considered to be greater than productivity, which in turn is greater than vegetation change, but this will depend on the type of land and the dominant land use.

The concept of range condition is used to denote the changes in vegetation composition, productivity, and land stability that occur when rangelands are grazed by domestic livestock. The purpose of measuring these changes in condition is based on a concern for the long-term productivity and stability of these rangelands. Condition assessments guide and inform the range manager on the improvement or decline in the long-term productivity of his land. Range productivity is stated as the purpose (if not the basis) of assessment, in the original presentation of the system based on quantitative ecology (Dyksterhuis 1949), so that whatever the basis, knowledge of both ecology and productivity are a part of the concept of range condition.

The predominant products of most rangelands are meat and fibre produced from grazing cattle, sheep and goats. Interest in other aspects, such as water yield or wildlife habitat may be important in particular localities, but overall they are secondary to livestock production. Furthermore, it is significant that the changes we seek to measure have been fashioned by livestock grazing. Hence range condition is measured in terms of the effect of grazing by livestock and wild herbivores on wildlife habitats, but is not used to assess the value of those habitats in the absence of grazing.

Despite general agreement on these concepts, there is considerable differences of opinion on how range condition should be measured. At the theoretical level these differences center on whether emphasis should be given to rangeland productivity or to vegetation change. As the main interest in condition centers on changes in productivity, it is natural for productivity-based methods to be developed (Humphrey 1949, Naveh 1975). On the other hand the so-called ecologically based methods (Smith 1979), which measure vegetation change, are regarded by others as a more fundamental expression of range condition (Dyksterhuis 1949, 1958; Gates 1979). In this framework, productivity is correlated with vegetation change, but not necessarily on a linear or even on a positive basis.

Recently, the practical deficiencies of the formal ecologically based methods have been detailed by Smith (1979). The first of these is that climax or near-climax vegetation is not necessarily best for a particular use, with the result that management may be directed towards attaining "good" or even "fair", rather than "excellent" condition. At best, this reduces the utility of the measurements because of problems in communication to land managers and the general community, while at worst it may lead to a complete misunderstanding. A common example of this is found in woodlands which have an inherent low animal productivity and which are "improved" by changing the composition towards a grassland. The second problem is that of defining the composition of the climax, which may be quite difficult where factors other than grazing are involved in determining the botanical composition (e.g. fire). The third problem is that the method must be modified to accommodate the presence of exotic species which have been deliberately introduced to increase forage production. Finally, measures of vegetation change may take no account of increases in erosion rate, which is a more serious manifestation of any change in resource condition. The first three of these difficulties may be overcome by appropriate adjustments. However, these adjustments usually have a production outlook, and in extreme situations may negate the original basis of the method. This raises doubts as to whether the formal structure of ecologically based methods can be sustained.

This paper examines the factors that should be considered in the development of methods of measuring range condition and develops a new theoretical framework which is free of the problems described.

The Concept of Range Condition

There are many factors or attributes involved in the concept of range condition. The primary attributes are changes in the vegetation, such as the botanical composition of the herbage, its total quantity or cover, and its invasion or emergence from a dominance by inedible shrubs or trees. Secondary changes may occur to soil attributes, such as infiltration rate, nutrient content or soil stability. Finally, changes may occur in production characteristics of the land, such as animal production ,water yield, wildlife habitat and amenity value. The common factor in these is that in all cases a change in condition refers to a *change* in status, relative to the *potential,* of each parameter within a particular land class. On this basis, the generalized definition of range condition is that it represents the present state of an attribute of a land unit relative to the potential of that attribute on the same land unit (see Stoddart et al. 1975). The term "range condition" is used in a qualitative way to represent the sum of the various attributes of condition, but it is not possible to make this summation quantitative because of problems in summing dissimilar quantities. Nevertheless, within a particular vegetation type the major change in condition may be represented by only one of these attributes and range condition may then be regarded as synonymous with the change in that attribute. In the

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well-known example of Dyksterhuis (1949) the major change was represented by botanical composition and in addition, changes in animal production were correlated with this change. Hence, the one index represented both attributes. However, this correspondence does not occur in all vegetation types, and attempts to make botanical composition a universal definition of range condition (Dyksterhuis 1958), are the basis of the problems detailed earlier.

It may be important here to emphasize the difference between the method and the purpose of measuring condition. The secondary and production characteristics of range condition are unlikely to be measured directly. Rather they will be expressed in terms of an index which is derived from vegetation measurement, so calculated to correlate with the attribute in question. Hence all attributes of condition may be measured in terms of components of vegetation, without suggesting that these are the only parameters of interest.

Another important aspect of range condition is land use. A change in attribute such as botanical composition is not in itself intrinsically good or bad unless interpreted in terms of a land use, such as grazing or conservation. Accelerated soil erosion is a change that may always be considered as undesirable (Ellison et al. 1951), but this is also subject to assessment in terms of acceptable levels of erosion in relation to water yield or animal productivity. This is a part of assessing the importance to be given to each of the attributes of condition and indicates that the overall condition of a land unit cannot be expressed in absolute terms.

Choice of Vegetation Measure

It is a basic premise that range condition will be measured in terms of the vegetation, whatever the attribute in question may be. A change in vegetation is the first symptom of a change in condition, it is the change which is most easily measured and it is the primary factor which leads to a change in other attributes such as erosion and reduced secondary productivity. It is only in research that direct measurement will be made of the secondary and production attributes, and then the purpose will be to devise an appropriate vegetation measurement that has a positive correlation to an attribute such as production.

Each vegetation measure will place different emphasis on the various growth forms of plants in the community and vary in the importance accorded to each species. Biomass gives primary emphasis to large species and in most rangeland communities most of the information will be confined to less than 10 species. Canopy cover is correlated with biomass, but gives more emphasis to prostrate plants. Basal cover is a related measure used to determine the density and composition of perennial grass communities.

Density and species frequency are measures that are related inversely to species size and hence give relatively greater emphasis to smaller and rarer species. Frequency is related to density (and within a species to biomass) on a curvilinear scale. It is also dependent on vegetation pattern and quadrat size (Greig-Smith 1964) and hence is more complex than the other measures.

The effect of the measure chosen to record vegetation change is illustrated in Table 1, using data from two rangeland communities. For the *Atriplex vesicaria* shrubland, biomass measurement indicates a dominance of *A. vesicaria,* while frequency gives prominence to the grasses, *Eragrostis* spp. and *Enneapogon avenaceus.* The relative importance assigned to the loss of *A. vesicaria* by overgrazing will depend on which measure is chosen for recording the change. For the semiarid woodland there are also differences between the methods in the importance afforded to each species. However, the differences are smaller and have less effect on the outcome, because the species represented are all of similar size and distribution.

As each measure emphasizes a different characteristic of the vegetation, an appropriate measure must be chosen with reference to the purpose of assessing range condition. Thus frequency may be the most appropriate measure for assessing the presence of rare species within a reservation and hence the "condition" of land under consideration for conservation purposes. However, most of the attributes of range condition that are of interest center on qualities emphasized by biomass (e.g. animal production) or cover (e.g. erosion). Therefore, it is concluded that there should be primary emphasis on biomass, or a related measure that may reflect biomass, such as the basal cover of perennial grasslands. For most species, canopy cover will be closely related to biomass and may offer a substitute, provided some information is obtained about the biomass-cover relationship of the species to guard against unwanted distortion of the importance of those species.

In this context, biomass is considered to be edible biomass, as this represents the parts of the plants of importance to animals. The stems and trunks of shrubs and trees do not represent a resource, except in terms of forestry, and hence are excluded while land condition is considered in terms of grazing. For inedible species

Table 1. Comparative biomass, foliar cover and frequency data for selected species within *Atriplex vesicaria* low-shrubland and semiarid low-woodland communities (Wilson and Tupper, unpublished data).

A. vesicaria low-shrubland

October 1976

Species	Biomass (kg/ha)	Cover (%)	Frequency[1] (%)	Percent composition Biomass	Cover	Frequency
Atriplex vesicaria	1220	17.6	43	67	33	17
Atriplex spp. (biennials)	108	5.4	41	6	10	16
Enneapogon avenaceus	190	11.3	65	10	21	26
Eragrostis spp.	202	16.4	80	11	31	32
Sclerolaena brachyptera	103	2.5	23	6	5	9

Semi-arid woodland (herbaceous spp.)

October 1978

Species	Biomass (kg/ha)	Cover (%)	Frequency[1] (%)	Percent composition Biomass	Cover	Frequency
Aristida jerichoensis	56	5.4	27	25	20	11
Enteropogon acicularis	24	1.7	33	11	7	13
Monachather paradoxa	21	1.5	37	10	6	15
Sclerolaena diacantha	39	6.0	61	18	23	24
Stipa variabilis	57	9.8	80	25	37	32
Thyridolepis mitchelliana	24	1.7	14	11	7	5

[1]Quadrat size 1m^2

within a grazed community (or edible species that are above browsing height), photosynthetic biomass is an appropriate equivalent to edible biomass.

The choice of measure is also related to the practical requirements of determining condition over wide areas of land and repeatedly in time. The condition of rangeland refers to the more permanent changes in the vegetation of a range unit induced by grazing, which are separate from the natural variation in time arising from season and amount of rainfall, and changes in cover and biomass arising from recent utilization by livestock. Hence there is a need to record vegetation in terms of a measure that is insensitive to recent growth and utilization. Unfortunately, such measures are those related to species number, such as density and frequency, which cannot be easily used because they do not represent the quantitative relationships between the species. A number of solutions are possible. The first is to use density or frequency as the basic measure of the vegetation and then to apply appropriate correction factors (which in the case of frequency would also involve power transformation) so that the data may then reflect the biomass or cover expected at the peak of the growing season. More simply, a stable measure that is correlated to biomass, such as basal cover, may be used in perennial grasslands (Foran et al. 1978, Christie 1978). However, it is unsuitable for other growth forms and may be tedious in arid areas where the basal cover is low. Alternatively, it is possible to reduce the importance of seasonal variation by expressing vegetation change relative to a "control" lightly grazed reference area or to measure at times when grazing is light. It is also possible in some communities to correct for utilization by estimating the amount of biomass or cover removed by grazing.

The requirement for assessment over wide areas of land in a minimum of time indicates that the most useful method will be one which is capable of both measurement and estimation. Estimates will be used in survey situations, but these will be based on training and checking by measurement, and be consistent with information derived from research situations where measurement is used. This requirement also favours biomass and cover which are easier to estimate than the more complex measure, frequency.

Selection and Classification of Species

All plant species contribute to the structure of a vegetation community so that on an ecological basis all species should be included in an assessment. Even ephemeral species and species that are unresponsive to grazing provide information relevant to the various attributes of condition. Nevertheless the measurement of all species separately may be tedious and unnecessary, and appropriate omission or accumulation of species should be considered. Of primary importance here is to ensure that these adjustments are consistent with the subsequent treatment of the data to form indices of change in the various attributes of condition under question. If the purpose of assessment is to determine change in productivity, the number of species measured can be reduced, both by omitting rare species and by the pooling of others into functional groups, where growth form and reaction to grazing are similar. If, on the other hand, a detailed analysis of vegetation change is required for other purposes, such an accumulation may be inappropriate.

A list of selected species for an *A. vesicaria* low shrubland is shown in Table 2. This community contains many ephemeral species. Most of these contribute to animal production and a number of them increase in amount as grazing intensity increases. They have been excluded, to avoid the restriction of measurement to short periods of the year and because it is considered that the year-long grazing capacity of this community is related to the presence of the biennial and perennial species. Nevertheless, it must be recognized that the omission of ephemerals may unfairly downgrade some condition classes.

In the assessment of the reaction of species to increased grazing pressure it is customary to classify species in terms of "decreaser" or "increaser" according to the change in their proportion in the community. For most vegetation types this classification is not required for the calculation of indices of vegetation change, except that such classification is useful to identify species that may be used as indicators of various stages of vegetation change. However, for some vegetation types, species classification becomes an integral part of the assessment. In the first instance, decreaser species may be allowed to score above the amount on the reference area (reference area value + 10 percentage units) without contributing to the index of change (Tainton et al. 1980). More importantly, the botanical composition may change several times as the grazing pressure is progressively increased and a simple index of change in botanical composition may award a lower score to intermediate locations than to badly degraded locations. For this reason, increaser species may be classified into type I (increase initially, but later decline as grazing pressure increases) and type II (increase over the whole range) with appropriate correction factors (Poulton 1959). Whilst such systems produce a progressive score of botanical change over the whole range of condition classes, it is not

Table 2. Examples of species present in an *Atriplex vesicaria* low shrubland (Barrier Range) and their classification for range condition assessment (Wilson and Tupper, unpublished data).

	Contribution to biomass	Perenniality	Response in grazed community	Classification for animal production
Astrebla lappacea	Moderate	Perennial	Increase	Desirable
Atriplex conduplicata	)	Biennial	Increase	)
	)			)Undesirable
A. lindleyi	)Moderate	Biennial	Increase	)group
	)			)
A. spongiosa	)	Biennial	Increase	)
A. vesicaria	High	Perennial	Decrease	Desirable
Arabidella nasturtium	Low	Annual	Increase	Exclude
Daucus glochidiatus	Low	Annual	Unresponsive	Exclude
Eragrostis setifolia	Low	Perennial	Unresponsive	Desirable
Helipterum corymbiflorum	Low	Annual	Increase	Exclude
Maireana georgei	Low	Perennial	Decrease	Desirable
Sclerolaena brachyptera	Moderate	Biennial	Increase	)
				)Desirable
S. diacantha	Moderate	Biennial	Increase	)group
S. divaricata	Low	Biennial	Increase	)
				)Undesirable
S. intricata	Low	Biennial	Increase	)group
Stipa variabilis	Moderate	Biennial	Increase	Intermediate
Tetragonia tetragonioides	Moderate	Annual	Unresponsive	Exclude

necessarily a linear or useful index of any the attributes of range condition.

The classification of species may be determined from field experience or by graphing the contribution of each species against indices of community change. The technique of reciprocal averaging (Hill 1973) may also be used. This produces an ordination of both species and locations which may be interpretable in terms of a gradient of grazing intensity or vegetation change (Hacker 1979). However, the ordination may overemphasize minor species and be distorted by rare species.

In Natal, South Africa, increaser species are classified into three groups (I—increase when fire or grazing is infrequent; II—increase with overutilization; III—increase with selective grazing) and the total amount of each category is used to indicate the reason for species change (Foran et al. 1978; Tainton et al. 1980). These classifications are a partial move from an index which simply describes botanical change, to one which assesses the value of that change in terms of animal production. It is in part a recognition that not all species change is deleterious and that desirable increaser species are a normal part of many rangeland communities (see Table 2). As a consequence, in assessing condition in terms of change in animal production, it is appropriate to classify species simply in the terms desirable, intermediate and undesirable (as determined by nutritive value, palatability, productivity, etc.), as is done in Western Australia (Payne et al. 1974) and by the U.S. Forest Service (Stoddard et al. 1975).

An example of this type of classification is shown in Table 2. In this case the perennial and biennial species are classified mainly on the basis of palatability. Desirable plants are those that are eaten readily at some period of the year. Undesirable plants are those that are never eaten, or are eaten only sparingly, usually when other forage is scarce. This group may also include plants that are poisonous or have harmful spines or seeds. An intermediate group, comprising plants that are eaten when immature, but are either of low quality or are avoided when mature, may be required in some communities. In the calculation of an index of condition, these species may be counted as half. This separation of change in animal production from change in botanical composition, readily allows for the incorporation of deliberately introduced species, which will be classified as desirable.

Indices of Condition

The condition of a range unit will be measured initially in terms of the quantity of each plant species present. To be of value to the range manager, this information must be reduced to an index which represents one or more of the attributes of range condition. This is usually accomplished by the calculation of a similarity index (between reference and test areas), of which the Dyksterhuis (1949) Quantitative Climax Index is but one example. A number of others are outlined by Williams (1976) and Orloci (1975). Eight of those with desirable characteristics for measuring vegetation change have been examined by Hacker (1979). His results show the degree of variation in vegetation change that arises simply from the type of index chosen to measure that change. Vegetation change is not an absolute characteristic of a vegetation, and requires some reference to a purpose of measuring that change.

Transformation

Before proceeding to the calculation of an index, it may be desirable to consider some form of data transformation. Expression of results in terms of percentages (Dyksterhuis 1949) is an example. Other possible transformations include species value/total value$^{0.5}$, (see Smartt et al. 1974) and species value^{x}. These may reduce the range of the data or change the relative emphasis given to high or low values; for the practical purpose of making the data less sensitive to recent grazing or to change the relative emphasis given to small or large species or species values. The outcome of some transformations is to reduce the quantitative and increase the qualitative nature of the information (Smartt et al. 1974). Hence percentage transformation eliminates some of the quantitative information in the original data so that it measures only botanical composition and ignores the total quantity of vegetation present. Such a transformation is undesirable for a method that seeks to inform about both of these aspects of vegetation change and hence is inadequate in situations where a decline in condition is expressed in both attributes (e.g. Foran et al. 1978). It may also serve to hide the real nature of change in the community, as an increase in the percentage contribution of a species may represent either a real increase in the quantity of that species, or a decline in the quantity of other species. The deficiencies of percentage transformation may be overcome by adding a second index of species quantity (Foran et al. 1978), but it would be easier to avoid the transformation. An example of quantitative climax scores for two *Atriplex vesicaria* communities, is given in Table 3. The relationship between these and scores derived from other indices, will be discussed below.

On the other hand, frequency data may be made more quantitative by the use of power functions (within a species) and correction factors (between species).

Vegetation Change

When land is to be assessed for its condition in terms of the preservation of natural communities, a measure of vegetation change will be appropriate. Examples of two such indices are shown in Table 3: the Quantitative Climax Index and Percent Similarity (the name is attributed to Hacker 1979). The Percent Similarity is similar to the Quantitative Climax Index in structure, but avoids percentage transformation. It is the sum of the lesser quantity of each species, on the reference and test locations, divided by the sum of all species on the reference location. The index is expressed as a percentage, from 100 (no change) to 0 (complete change). This is a more useful index than the Quantitative Climax Index, because it makes allowance for declines in species quantity, as well as species composition. This procedure is

Table 3. Examples of indices of condition obtained from foliage cover measurements of *Atriplex vesicaria* communities (Wilson and Tupper, unpublished data).

	Riverine Plain, N.S.W.				Barrier Range, N.S.W.		
	Indices of vegetation change		Index of productivity		Indices of vegetation change		Index of productivity
Location No.	Percent similarity	Quantitative climax	Relative cover desirable species	Location No.	Percent similarity	Quantitative climax	Relative cover desirable species
6	100	100	100	8	100	100	100
4	100	100	100	6	79	87	85
5	100	95	100	3	78	80	95
3	49	68	52	1	41	42	73
8	36	49	43	2	28	26	100
7	35	56	30	4	24	25	56
2	22	34	26	5	23	24	30
1	10	10	16	7	22	25	55

outlined in the National Range Handbook (USDA 1976), but the authors understand that it is not often used. Using this method in the Riverine Plain example in Table 3, location numbers 3, 8 and 7 are appropriately penalized for a reduced density of species as well as a change in composition, whereas the first change is not recognized by the Quantitative Climax Index. However, as mentioned earlier, there are many indices of vegetation change (or similarity), and the one chosen will depend on the emphasis to be given to qualitative or quantitative factors, and the particular purpose of the measurement. In retrospect it appears that the Quantitative Climax Index is misnamed.

Productivity

If change in animal productivity is correlated to change in vegetation attributes in a positive way, then the index of vegetation change may also be used as an index of production. However, in other instances the changes will not be correlated. This will occur in situations where increaser species are valuable and productive for livestock grazing. The example of *Sclerolaena* spp. is shown in Table 2, and *Danthonia caespitosa* (Wilson et al. 1969) is another. In these situations, animal production will be related to the total production of useful plants and an index derived from the summation of the biomass or cover of these species will best serve as an index of animal production. An example of this is shown in Table 3. For the Riverine Plain community, the relative cover of desirable species is approximately the same as the Percent Similarity Index, and no benefit arises from the separation of the two. However, for the Barrier Range community, the contribution of *Sclerolaena* spp. leads to a substantial difference between the two indices for locations 3, 1, 2, 4, and 7. The condition of these locations, in terms of grazing, is not as low as the degree of vegetation change would suggest. In this case it is appropriate to express the results in terms of two indices; the first to be used to characterize condition in terms of vegetation change, and the second in terms of grazing value.

Erosion

Physical erosion, or more frequently, a decline in the physical characteristics of the soil surface, is the most serious manifestation of a decline in range condition because of its long-lasting and progressive impact on production attributes. As noted by Ellison et al. (1951), condition should be based primarily on soil stability and only secondarily on forage value. He considered that condition is always unsatisfactory unless the soil is stable and that forage value is only considered when the stability is assured. He also suggested that the two factors are not additive. This is consistent with the proposal in this paper, that the various attributes of condition should be measured separately.

Measures of erosion and related soil changes will differ from site to site, according to the type of change experienced. Foran et al. (1978), working in the rangelands of Natal, expressed soil stability in terms of the total basal cover of herbaceous plants. In areas subject to sheet erosion, point sampling can be made of the proportion of soil with a sealed or eroded surface. An example of data from the use of this procedure is shown in Table 4. In this semiarid woodland community, soil erosion is a major manifestation of lowered condition. Indirect measure can also be obtained from changes in the total canopy cover of herbaceous plants. In the example shown in Table 4, total herbage cover reflects the effects of both erosion and shrub encroachment. The Percent Similarity Index or other measures of vegetation change are of little value in this community as there are no suitable reference areas that are not either shrub invaded or heavily damaged in the past.

Other forms of erosion, such as gullying, are not readily measured and this suggests that the status of the soil will often be estimated by subjective ratings, based on indicators such as bare soil surface, erosion pavement, rills and gullies, pedestalling and soil deposition. The ratings developed will be site specific as the importance of each indicator will vary with the site.

Table 4. Indices of condition for a semiarid woodland in New South Wales, in which declining condition is characterized by both erosion and increasing density of inedible shrub (Wilson, et al., unpublished data).

Location No.	Relative[1] herbage cover (%)	Inedible shrub cover (%)	Soil[2] erosion index	Percent[3] similarity
4	100	11	34	100
9	79	10	54	38
5	74	30	12	51
1	72	15	58	35
8	72	12	88	29
3	65	7	87	25
10	56	30	61	36
11	36	33	36	32
2	25	32	95	17
7	24	25	91	21
6	7	34	87	12

[1]Cover of desirable perennial species, relative to location 4.
[2]Percentage of eroded soil surface.
[3]Relative to location 4, includes shrub and herbage species. (Not different to quantitative climax indices in this instance).

Shrub Encroachment

The encroachment of inedible shrubs and trees into semiarid rangelands represents a community change that may be viewed either as a change in botanical composition or as a separate vegetation attribute: the herbaceous-woody species balance. In terms of a change of botanical composition there is some difficulty in measuring shrub weight or cover in equivalent terms to herbaceous plants, but appropriate indices of condition could be constructed in this way. Alternatively, the measurements may be confined to the herbage layer. The total herbage cover (see Table 4) is in itself a direct measure of the effects of shrub encroachment and may be used as an integrated index of condition in terms of productivity. In terms of separate attribute of condition, a simple index of shrub encroachment can be constructed. The nature of the effect of shrub biomass on herbage biomass is shown in Figure 1. This type of relationship, for either biomass or cover, could be determined for each community type and used to develop a scale for assessing the condition of shrub cover. Such an index of shrub encroachment will be directly related to potential animal production.

Such indices of shrub encroachment may be an incomplete measure of the situation, particularly when the shrubs are not fully

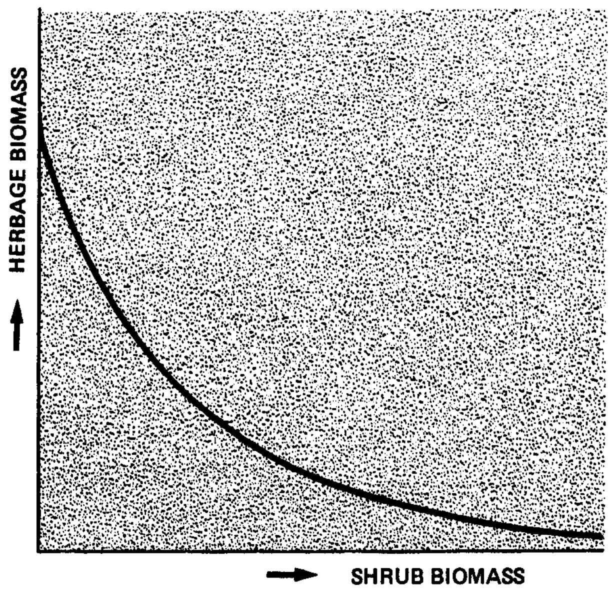

Fig. 1. *Relation between herbage yield and shrub biomass (adapted from Beale 1973).*

established and represent an incipient rather than a current problem. Separate measure of shrub seedling density may be required and these would be considered as an assessment of the trend in condition, rather than condition itself.

Discussion

There are a number of steps involved in the development of any method of range condition; the choice of vegetation measure, the species to be included and their classification, and the type of index to be constructed. At each step, the choice made from the available methods and systems is dependent on the current land use and the attribute of condition to be assessed. The appropriate concepts and methods of ecology may be incorporated into an assessment system, but this does not lead to a single ecological method or scale that may be regarded as a universal standard of condition. Range condition is a concept, like succession, which manifests itself in different forms according to the community type and to the disturbance applied. In particular, the community changes may be either quantitative or qualitative, or both, and the consequences of each change for soil stability or secondary production will differ according to the type of species involved and the erodibility of the soil. The idea of an "ecological method" based on some absolute change in botanical composition has been appealing. It has been supported by general statements that it is an "objective ecological approach" (USDA 1976) without acknowledging that there are other attributes of change in condition or even that there are a number of ways of measuring change in botanical composition. It has gained credence because of an assumed general relationship between animal productivity and change in botanical composition (Dyksterhuis 1949). In other situations this method has required extensive modification to make it functional (Foran et al. 1978, Smith 1979). It is now apparent that it is only one of a number of possible methods and that it provides only a part of the framework of range condition.

There has been a long standing difference of opinion between authors on whether range condition methods should be based on productivity or ecology (Humphrey 1949; Dyksterhuis 1949). It may now be concluded that ecological and productivity-based methods are not mutually exclusive. Changes in botanical attributes and change in production attributes are separate, but related aspects of range condition. Neither can be said to be more important than the other without reference to the purpose of assessment. In general, ecological methods require the consideration of production attributes for interpretation, while productivity is a state of the vegetation that is dependent on species composition and density and requires ecological techniques for its measurement. Range condition is not wholly defined by, or equivalent to, botanical composition as previously claimed by Dyksterhuis (1958).

In practice, composite indices of various attributes of condition may be constructed (e.g. Foran et al. 1978), but these then refer indirectly to a production attribute of condition. Perhaps it is inevitable that all indices of condition on grazed rangeland will refer either to soil stability or to production change (animals and other products), as in such agricultural situations vegetation change in itself does not have a value. It is the importance of that change in terms of production characteristics that is of concern. Agriculture in general is based on the modification or replacement of natural vegetation, and rangeland, although only partially modified, must be assessed on the same basis. Also, in most parts of the world, the concept of vegetation change from original has no basis as no original vegetation remains. In such cases the benchmark or reference vegetation will be constructed in terms of a production attribute. It is therefore concluded that range condition should be expressed as separate indices of soil stability and of important production attributes, despite the use of ecological techniques to measure the vegetation. Associated scales of vegetation change may also be derived in appropriate situations, but these will be used for the separate purpose of assessing land for the conservation of plant communities.

A common subjective classification of condition assessments across all rangeland types could be developed from within the framework presented by Ellison et al. (1951). A re-interpretation of this is as follows:

Excellent condition: soil stable, productivity good
Good condition: soil stable, productivity diminished
Fair condition: soil unstable, productivity good
Poor condition: soil unstable, productivity diminished.

This would avoid differences in interpretation that currently occur between range types and between countries.

One consequence of this interpretation of range condition, is that each range type may have a different system of assessment. Each system will be based on the type of degradation found under current land use and on the structure of the vegetation community. The detail of methods may also change as new insights are gained into the function of those communities and the value of their component species. Nevertheless, the one set of data may be applied to assessments for many land uses, as the major differences between systems will be in the construction of condition indices, rather than in the technique of field measurement.

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Predation Losses of Cattle in Alberta

MICHAEL J. DORRANCE

Abstract

Coyotes *(Canis latrans)*, black bears *(Ursus americanus)*, and wolves *(Canis lupus)* were reported responsible for 35, 31, and 16%, respectively, of confirmed predation losses of cattle in Alberta during 1974-78. Coyotes selected for calves over adults, and adults over yearlings, black bears selected for calves over yearlings, and yearlings over adults, and wolves selected for calves and yearlings over adults. Predation of cattle by coyotes, bears, and wolves peaked during March-June, May-July, and August-September, respectively.

Little information is available on predation losses of cattle, even though the value of losses from predation are comparable for cattle and sheep in the United States (Anon. 1978, Gee 1979). In Alberta, the value of cattle lost to predation from coyotes, black bears, and wolves exceeds that of other species of livestock.[1] This paper describes the monthly chronology and age distribution of predation losses of cattle in Alberta, Canada during 1974-78.

Methods

Since 1974, the Alberta government has paid compensation for predation losses of livestock reported by producers and investigated by government personnel. Criteria used for identification of predation were described by Roy and Dorrance (1976). Death or injury of livestock was classified as (1) confirmed as predation, (2) predation probable but not confirmed, (3) other than predation, and (4) undetermined. Data recorded included numbers and species of livestock killed or wounded, age of livestock, estimated body weight, herd or flock size, date of predation, predator responsible, and legal land description. This paper summarizes data of confirmed losses of cattle from predation during 1974-78 for which the date of predation could be determined within 1-4 days.

Data were separated into five major ecosystems; i.e. mixed forest, northern parkland, southern parkland, foothills and mountains, and prairie (Dorrance and Roy 1976). The parkland was subdivided into a northern and southern unit separated by the Bow River because distribution and population densities of predators appeared to differ between these areas. Data from the foothills and mountains were combined because of relatively low numbers of cattle.

An index of susceptibility of cattle to predation was calculated by dividing the total number of cattle killed or wounded by each predator in each ecosystem by the percentage of all cattle within the ecosystem. The index represents a valid estimate of susceptibility of cattle to predation if (1) the percentage of predation losses reported by stockmen remained constant among ecosystems, and (2) the probability of finding and identifying predation losses remained constant among ecosystems. The validity of the first assumption is unknown. Increased forest cover and rugged topography probably reduced the probability of finding predation losses; thus, the index is probably biased downward in the foothills and mountains, mixed forest, and to a lesser degree in the northern parkland.

Selectivity by predators for calves, yearlings, and adults was evaluated with a chi-square test between age composition of predator kills and age composition of 36,581 cattle (87 calves:36 yearlings:100 adults) pastured on provincial grazing reserves during 1976-78.[2]

Results and Discussion

Confirmed predation losses totaled 1,520 cattle killed or wounded in Alberta during 1974-78. Coyotes, black bears, and wolves were the major predators of cattle and were reported responsible for 35, 31, and 16% of confirmed losses, respectively. An additional 8% were attributed to either wolves or bears. Predators responsible for the remaining 10% were classified as dog family (n=52), dog (n=7), cat family (n=8), mountain lion *(Felis concolor)* (n=15), lynx *(Lynx canadensis)* (n=3), grizzly bear *(Ursus arctos)* (n=11), golden *(Aquila chrysaetos)* or bald *(Haliaeetus leucocephalus)* eagle (n=3), and unknown (n=42).

About 4/5 of the predation losses occurred in the mixed forest and northern parkland where 2/3 of the cattle were raised (Table 1). However, susceptibility of cattle to predation was 4-9 times greater in the foothills and mountains than in the mixed forest, 2-9 times greater in the mixed forest than in the northern parkland, and comparatively low in the prairie and southern parkland (Table 1). In general, susceptibility of cattle to predation increased with increased forest cover and was accentuated by rugged topography.

Age composition differed significantly among cattle killed by coyotes, bears and wolves ($P<0.01$). Compared with a ratio of 87 calves:36 yearlings:100 adults on provincial grazing reserves,[2] coyotes selected for calves over adults ($P<0.01$), and adults over yearlings ($P<0.05$); bears selected for calves over yearlings, and yearlings over adults ($P<0.01$); and wolves selected for calves and yearlings over adults ($P<0.01$) (Table 2).

All major predators selected for calves over adults (Table 2), but coyotes were the most selective ($P<0.01$). Seventy-eight percent of the calves killed by coyotes were 1 month of age or less, and 32% were killed at 1 day of age (Fig. 1). Thus, monthly chronology of coyote predation coincided with the calving season and peaked sharply during March-June in Alberta (Fig. 2). Unlike bears and wolves, coyotes selected for adults over yearlings (Table 2, $P<0.05$), probably because coyote predation of older age classes of cattle was most often associated with calving or defense of calves.

Black bears selected for calves over yearlings, and yearlings over adults, and were intermediate in selectivity between coyotes and wolves (Table 2, $P<0.01$). The pronounced increase in bear predation between April and May reflected emergence of bears from hibernation and departure from den sites (Tietje and Ruff 1980), and movement of cattle to more remote pastures. Bear predation peaked during May-July and declined during August and September (Fig. 2) probably because alternative sources of food (e.g. berries) were available. The gradual decline in percentage of kills older than 5 months of age (Fig. 1) and selectivity of calves over yearlings also suggest that the decline in bear predation during late

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Acknowledgment is made to Dr. G.R. Whenham (deceased), Alberta Agriculture, W.N. McLachlan, Alberta Energy and Natural Resources, and P. Erickson for special assistance.

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[2]Unpublished data. McLachlan, W.N. December 1980. Alberta Energy and Natural Resources, 9915-108 Street, Edmonton, Alberta T5K 2C9.

Table 1. Distribution of cattle, and susceptibility of cattle to predation in Alberta. Indices of susceptibility of cattle to predation were calculated by dividing the total number of cattle killed or wounded by the percentage of cattle within the ecosystem. Numbers of cattle killed or wounded are in parentheses.

Ecosystem	Distribution[1] of cattle (%)	Relative susceptibility of cattle to predation: Coyote	Black bear	Wolf	Mountain lion
Foothills and mountains	1	94 (94)	58 (58)	63 (63)	1 (1)
Mixed forest	17	10 (176)	14 (232)	9 (149)	0 (0)
Northern parkland	48	5 (221)	4 (188)	1 (29)	0 (14)
Prairie	26	2 (55)	0 (0)	0 (0)	0 (0)
Southern parkland	8	1 (6)	1 (5)	0 (0)	0 (0)

[1]Data provided by Alberta Agriculture Statistics Branch, December, 1980.

Table 2. Age composition of cattle killed by predators.

Predator	Number of cattle	Percent: Calves	Yearlings	Adults	Ratio calves:yearlings:100 adults
Coyote	532	93	1	6	1547:16:100
Black bear	466	71	11	18	394:61:100
Wolf	241	54	23	23	235:100:100
Mountain lion	13	69	23	8	

summer and fall resulted from increased size of calves.

Wolves selected for calves and yearlings over adults ($P<0.01$), but exhibited no apparent preference between calves and yearlings ($P>0.05$, Table 2). Most calves killed by wolves were 5–9 months of age (Fig. 1). Thus, an increase in the size of calves apparently did not deter predation by wolves. Wolf predation did not peak until August and September (Fig. 2), although calves were available throughout the summer. Wolves tended not to prey on the youngest calves, perhaps because preferred, alternate sources of food were more available during May–July. During early summer wolves select newborn fawns and calves of wild ungulates, which are helpless unless defended by an adult (Mech 1970:176). Perhaps wolves prefer wild ungulates, but switch to domestic cattle in late summer when fawns and calves of wild ungulates become more difficult to catch.

A small sample size prevented statistical analysis of mountain lion predation, but they were apparently intermediate between coyotes and wolves in selectivity for age classes of cattle (Table 2).

Closer surveillance of cattle during calving time should reduce predation by coyotes, particularly in the forested regions of Alberta. Movement of cows with small calves to remote, forested pastures should be deferred, to reduce the probability of predation by coyotes and bears. In areas with a history of wolf predation, it may be desirable to develop rotational grazing systems so that cattle are removed from remote forested pastures during late summer.

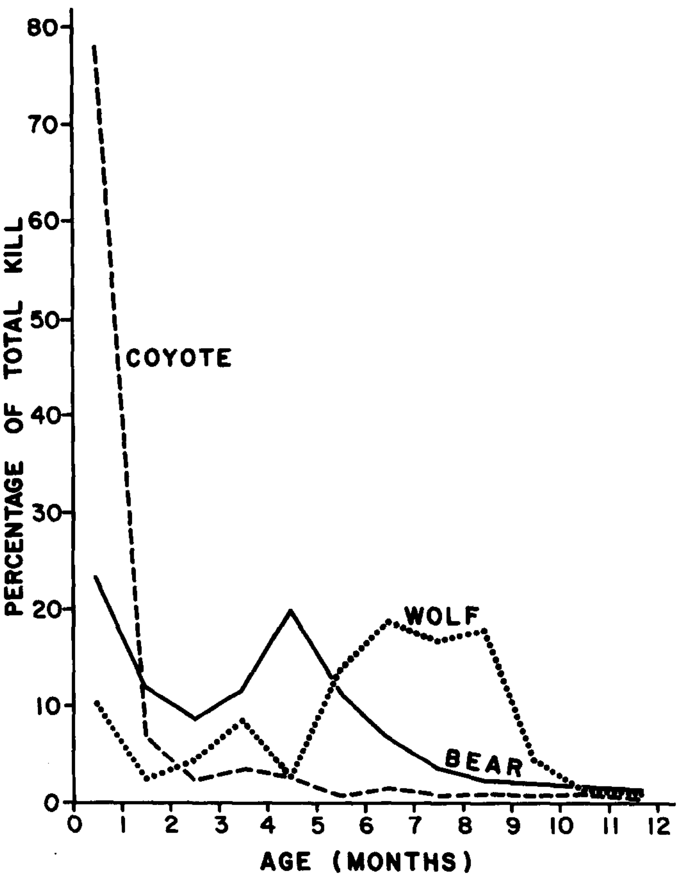

Fig. 1. *Age distribution of calves killed by predators.*

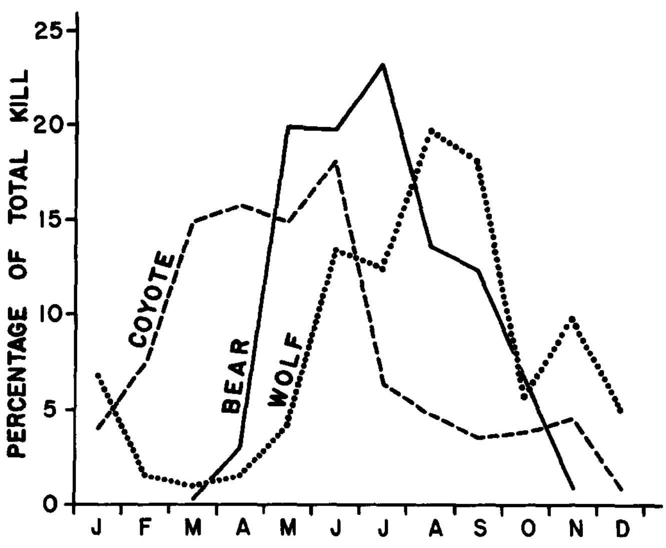

Fig. 2. *Monthly chronology of predation losses of cattle in Alberta.*

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SOUTHERN	45.00	25.00	65.00	32.00	205.00	45.00	25.00
FLORIDA	45.00	25.00	65.00	32.00	205.00	45.00	25.00
TEXAS	43.00	21.50	63.00	30.00	203.00	43.00	23.00
UTAH	43.00	23.00	63.00	30.00	203.00	43.00	23.00
WYOMING	43.00	22.00	63.00	30.00	203.00	43.00	23.00
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How Komondor Dogs Reduce Sheep Losses to Coyotes

JOHN C. MCGREW AND CINDY S. BLAKESLEY

Abstract

Nine Komondor dogs were observed guarding lambs in two 65-ha enclosures for 21 days each. Each enclosure had a resident coyote chosen for sheep-killing ability. Komondorok guarded sheep by being near the flock and actively defending it when necessary. Guarding was most effective in the area where the dogs spent most of their time. Aggressive dogs were generally more successful protecting their sheep. The sheep learned to run to or stand with the dogs when attacked, and usually bedded with the dog. The coyotes learned to attack the flock when the dog was not present. Effectiveness of Komondor dogs can be enhanced by exploiting breed characteristics.

Livestock guardian dogs are common in the Old World (Coppinger and Coppinger 1978) but were virtually unknown in the United States before the mid-1970's. However, since the 1972 Presidential ban on the use of Compound 1080 and other toxicants, dogs have enjoyed increasing popularity as an environmentally acceptable means of reducing coyote *(Canis latrans)* predation. A majority of dog owners polled rated their dogs as good to excellent at reducing sheep losses to coyotes (Green and Woodruff 1980, Newbold 1980). Articles by stockmen (Gerber 1974, Adams 1978) agree that dogs reduce losses but offer little reliable evidence of how this is accomplished. Some authorities are skeptical about the use of guardian dogs (Wade 1978).

The U.S. Fish and Wildlife Service, Denver Wildlife Research Center, conducted a brief field evaluation of one popular guardian breed, the Hungarian Komondor, to collect empirical data on the effectiveness of dogs. Linhart et al. (1979) trained four adult Komondorok (plural form) to attack coyotes and stay with sheep in fenced pastures. Sheep kills by coyotes decreased significantly during and following the use of the dogs, suggesting that they were a deterrent to coyote predation. The Denver study was unable to determine how Komondorok reduced predation, although pheromones, barking, coyote neophobia, and coyote-dog encounters were suggested as possible explanations (Linhart et al. 1979:240).

In this report we present the results of a field trial of Komondorok guarding sheep under controlled conditions. We also offer recommendations for increasing the effectiveness of Komondor dogs as flock guardians. Our objectives in this study were to determine how the dogs protected sheep from a coyote, particularly the behavioral interactions involved, and to answer some of the questions raised by Linhart et al. (1979).

During research the authors were Ph.D. and M.S. candidates, respectively, in the Department of Zoology and Entomology, Colorado State University, Fort Collins, Colo. 80523.

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Finally, they wish to thank J. Green, P. Lehner, and E. Pexton for their helpful comments on an early draft of this manuscript.

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Methods

We conducted field trials with 9 Komondor dogs in two 65-ha (160-acre) enclosures at the U.S. Sheep Experiment Station (USDA/ARS), Dubois, Ida. The dogs are subjects of a 3-year study of the efficacy of using Komondor dogs to protect sheep from coyote predation. At the time of the study, they were 26 months old.

The USSES is located on the Upper Snake River Plain, a province characterized by extensive lava fields (Hunt 1974). The terrain is level to slightly rolling, but broken by irregular rocky mounds and folds formed by lava flows. The vegetation is primarily sagebrush-bunchgrass (Blaisdell 1958), with the principal plants in the enclosures being sagebrush (*Artemisia* spp.), antelope bitterbrush *(Purshia tridentata),* rabbitbrush (*Chrysothamnus* spp.), and wheatgrasses (*Agropyron* spp.). Pricklypear cactus (*Opuntia* spp.) were also common in the enclosures.

The enclosures in which the trials were conducted are part of a full section (260 ha) set aside for predator research at the USSES. The enclosure fences are constructed of 2.5 cm × 5.0 cm wire mesh, 2.4 m high with a 31-cm wire-mesh overhand at the top of the fence and a buried 62-cm wide apron at the bottom (Fig. 1). The research area is located approximately 3.2 km from the station headquarters and is readily accessible by road. Dirt roads parallel all of the fences and connect major features within each 65-ha enclosure. The northwest (NW) and southeast (SE) enclosures were used simultaneously in the present study.

We conducted trials from 15 May to 21 September 1980. On 14 May we released the first 25 lambs (white face × Suffolk crossbred, average weight: 25 kg) into each enclosure. These lambs, and all others used during the summer, had no previous experience with dogs or coyotes. Water was available ad lib in tanks filled 2 or 3 times per week. The sheep were able to find sufficient natural forage until about mid-July, after which we supplemented their diet with alfalfa pellets fed from a large feeder located near the

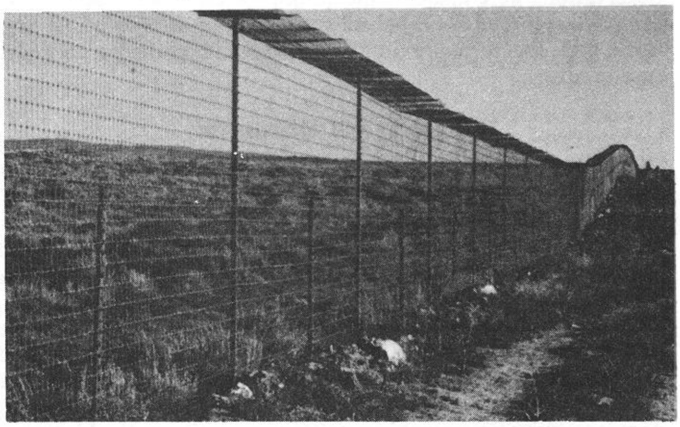

Fig. 1. *Detail of enclosure fence of the coyote research facility, U.S. Sheep Experiment Station (USDA/ARS), looking east on the north side of SE enclosure. Note 31-cm overhang at top, mesh construction, and rocks covering 62-cm aprong at bottom.*

Table 1. Schedule of trial phases and observation periods. Observation periods alternated between the 2 dogs under study during each trial. Observations were conducted on days marked "x."

	Introductory Phase												Performance Phase								
							Period I							Period II						Period III	
Trial day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
AM	[1]	X	X	X			[2]	X	X	X				X	x	x				X	X
PM	X	X	X				X	X	X				X	X	X				X	X	[3]

[1]Dog introduced
[2]Dog and sheep released from 0.8-ha pasture
[3]Dog removed

water tanks. Sheep killed during the summer were removed daily and replaced periodically so that flocks usually numbered 25 at the beginning of each trial.

We released a single adult male coyote into each of two enclosures at the beginning of the trials and left it undisturbed for the remainder of the summer. Both coyotes were 3 years old and weighed about 11 kg when released. They were selected from the USSES kennels on the basis of their ability to kill sheep in pen trials. Both were fitted with radio transmitter collars before release into the enclosures.

Each trial consisted of two phases (Table 1). During the Introductory Phase we placed the dog under observation with the lambs in a 0.8-ha (2-acre) pen in one corner of the 65-ha enclosure. We provided food and water for the sheep and dog in the pen. The introduction allowed a brief time for the dog to become accustomed to the vegetation and terrain features, and for the dog and sheep to adjust to each other. On Day 7 we released the sheep and dog from the pen and allowed them access to the entire 65-ha enclosure. The trial then continued for an additional 14 days (the Performance Phase).

One of us visited both enclosures every day to insure sufficient food and water were available and to remove sheep carcasses. Aside from these daily visits, we did not interfere with the dog in any way once its trial began. With few exceptions, the dogs were unaware of our presence in the enclosures during observations. A small booth mounted on the bed of a military surplus lift-bed truck served as an observation tower. The truck could be moved, and usually it was parked approximately in the middle of the active enclosure. Visibility from the booth, which could be raised to height of about 5 m, was generally good, although some parts of both enclosures were obscured by vegetation or terrain features.

We observed the dogs, sheep, and coyotes on 11 of the 21 days of the trial (Table 1). Morning sessions began at first light and lasted until the coyote and sheep became inactive, usually by 0930. Evening sessions lasted from 1700 to 1800 until dark. We occasionally made unscheduled observations on other days of the trial. All observations were made by the authors or an experienced technician. We recorded location, movements, and activity of the dog, flock and coyote continuously in field notebooks or on audio casette tapes.

Results and Discussion

The dogs patrolled, barked (especially at night), and scent-marked around the sheep as suggested by Linhart et al. (1979). None of these behaviors appeared to repel the coyotes permanently. Rather, the dogs protected sheep by being near the flock and actively defending it. In 79 of the 153 coyote-sheep interactions which we observed, the sheep either stayed with or ran to the dog, and in 75 of the 79 the dogs stood between the sheep and the coyote or chased the coyote away. The dog ran to the sheep and repelled the coyote in 5 additional instances. Sheep were never attacked while with a dog. The need for active defense explains why tethered dogs were sometimes unable to prevent predation in the Linhart et al. study.

The dogs all formed an attachment to one area of the enclosure, usually the area around the gate. Linhart et al. (1979) noted a similar pattern. Their dogs roamed over about 20% of one 130-ha pasture, and movements of their dogs, like ours, were related to the location of food, water, and other dogs. Our dogs spent an average of 74% (range 30 to 98%) of their time within 90 m of the main gate. The overall result of this site fidelity was that the dogs guarded most effectively when the sheep were within the dogs' preferred areas.

The dogs' attraction to sheep offset their site fidelity to some extent. The sheep left the dogs' areas several times each day for food and water. Some of the dogs were indifferent to sheep and rarely followed when they left the gate. Others followed only briefly or for short distances. Only one dog (Cyborg) regularly accompanied sheep for periods of time as long as an hour.

Being with the sheep was only one component of guarding behavior. The dog also had to repel the coyote when necessary, sometimes repeatedly. We observed a total of 141 interactions between dogs and coyotes ranging in duration from 2 seconds to 25 minutes. Eighty-four of the interactions involved the dog interrupting a coyote attack on sheep. Aggressiveness varied from dog to dog. One male showed little reaction to the coyote other than approach and raised-leg urination (RLU). One of the females was chased almost 700 m in her only recorded encounter with the coyote. She stayed away from the gate for 2 days afterward. Buff, Cyborg (♂♂), and Calahan (♀) unhesitatingly chased coyotes on their first exposure and every chance thereafter. Chases were rarely longer than 50 m. This lack of predisposition for chasing appears to be a Komondor breed characteristic.

Aggressiveness sometimes varied from day to day for the same dog. For example, late in the evening of Day 18 of her trial, Babe actively defended her sheep from the coyote for over 2 hours. The coyote approached the flock at least 10 times during this period, and Babe repelled it each time. Yet, the next morning the coyote managed to separate the sheep from Babe and to drive them away from the gate. She made no attempt to follow or chase the coyote, perhaps because the sheep quickly left her preferred area.

Finally, aggressiveness increased over the course of the trial for some dogs. Cecily ran from the coyote on her first encounter (Day 8). On Day 10 she chased the coyote away from the flock, but then turned and ran when it challenged her. Finally, on Day 15 she chased the coyote away several times without retreating.

An important factor not noted by Linhart et al. (1979) is the behavior of the sheep. In our study the sheep appeared to learn to avoid the coyote by going to or staying with the dog. In over half of the coyote attacks, the flock stood with or ran to the dog. As the study progressed the sheep established their bedding ground at the gate and spent an increasing amount of time there. The sheep also increased the dogs' effectiveness by detecting the coyote. Komondorok have good olfactory and visual acuity (pers. obs.), but they rarely detected the coyote before the sheep did.

Despite their selection for similar sheep-killing ability, there was a distinct difference in the predatory behavior toward sheep shown by the two coyotes, the NW coyote being noticeably less persistent and aggressive. The sheep responded by adopting two different defensive strategies. The flock in the NW enclosure stood and faced the coyote on 34 of 53 encounters, whereas the SE flock relied on the proximity of the Komondor dogs for defense from the more

Table 2. Results of the 9 Komondor sheep-guarding trials.

Dog	Sex	Total observation time (hours)	Total kills: Introductory phase	Performance phase: Period I	II	III
SE Enclosure						
Babe	F	38[a]	4	2	2	
Buff	M	59	1	2	2	
Cecily	F	75	5	3	1	1
Calahan	F	70		2	1	
Cyborg	M	64		1		
NW Enclosure						
Bo	M	62				1
Bess	F	81		1	1	
Breese	F	61	1	2	2	
Blue	F	73		1	1	

[a]Time reduced by bad weather

aggressive coyote. They stood and faced the coyote on only 11 of 93 encounters.

In contrast, certain sheep behaviors increased their vulnerability. The flock in the NW enclosure was never strongly cohesive, and several kills resulted from fragmentation of the flock (Blakesley and and McGrew, unpub. data). The sheep in both enclosures often became active before dawn, especially during warm weather, and moved away from the dogs to graze or go to water. This behavior exposed them to predation from the coyotes, which were most active just before dawn, and often resulted in a sheep being killed less than 200 m from the gate with no interfence from the dog.

Both coyotes spent considerable time within 100 m of the flock (at least 26% of the total active time for the SE coyote), and both coyotes regularly challenged the dogs. If a dog ran from either coyote, the coyote would chase. Some dogs chased the coyote, and it ran just far enough and fast enough to avoid the dog. Number and duration of coyote-dog interactions differed from dog to dog. Buff, who was somewhat clumsy and slow, was challenged more often and longer than was Cyborg, who nearly caught the coyote on two occasions.

Sheep losses during our study were higher than anticipated: of 89 sheep exposed to the coyotes over the summer, 37 were killed (Table 2). However, our objective in this experiment was not to determine *if* Komondork could guard sheep. We accepted the experiences of stockmen and the results of Linhart et al. (1979) as proof of the breed's potential. Rather, we hoped to observe *how* the dogs protected sheep, the development of guarding behavior, and the mechanisms involved. This information could then be used to improve rearing and training methods and to identify situations most suited to the temperament of the breed.

Our procedure had the effect of challenging the dogs' guarding abilities by placing them at a disadvantage in relation to the coyote. We trucked them 3 or 4 at a time over 1000 km from Fort Collins to the USSES and housed them in strange kennels. In addition, we made no effort to familiarize them with the enclosure prior to Day 1 of their trials, when we simply put them with an unfamiliar band of sheep in a small pen. The pen fences limited the range of the dogs and sheep, but did not exclude the coyotes, who dug holes under the fences and killed a total of 11 sheep during the Introductory Phases of four different trials (Table 2). The 65-ha enclosures used after Day 7 were much larger and rougher than the 4- to 6-ha grassy pastures in Colorado where the dogs had previously worked.

The dogs also had to contend with coyotes chosen for aggressiveness and sheep-killing ability. We did not feed the coyotes, and, although they killed small birds and mammals on occasion, sheep were their principal prey. Furthermore, the enclosure fence limited the coyotes to 65 ha and a maximum distance of 1100 m from the flock. This level of predation pressure would be unlikely in a normal production situation.

Wade's argument (1978) that the adaptability of coyotes would limit the effectiveness of guard dogs was supported only in part. The coyotes appeared to assess the dogs' abilities and to kill sheep when the dogs were not with the flocks. However, the dogs also adapted to the coyote and changed their behavior, even during the short trial period. Cecily showed the greatest improvement, and her increased aggressiveness resulted in reduced predation from Period I to Period III of her Performance Phase (Fig. 2).

In addition, the behavior of the sheep changed, generally improving the dogs' effectiveness in guarding. The dynamic nature of the dog-sheep relationship (and the possibility of enhancing the relationship through training) suggests that it may be an effective counter to flexibility in coyote behavior.

The dogs in this study were relatively young and continued to show improvement after 3 weeks (Table 2). In our study and in Linhart et al. (1979), even the best dogs did not totally eliminate coyote predation. Guard dogs are not a perfect method and should

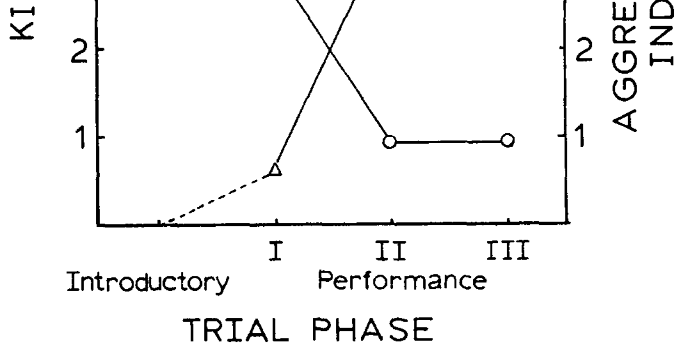

Fig. 2. *Coyote predation declined as Cecily's aggressiveness increased during the course of her trial. The Aggressiveness Index is calculated by the formula*

$$AI = \frac{\Sigma(I_i \times D_i)}{\Sigma D_i}$$

where I=intensity of dog-coyote interactions on a 7-point scale and D = duration of the interactions (N=23 interactions). No interactions between Cecily and the coyote were noted during the Introductory Phase.

be considered one of a variety of control methods which can be combined with sound husbandry practices to reduce sheep losses (Lehner 1976, Anonymous 1980).

Wade's suggestion that unattended Komondorok might be a hazard to animal or human life was unsupported. Linhart et al. (1979) reported that one of their dogs attacked and killed sheep. Some livestock producers have also complained of their dogs chasing sheep. However, none of our dogs were observed harassing sheep at any time during the summer, perhaps due to their early social experience with sheep. As a result, even naive sheep quickly accepted the dogs' presence near the flock. Komondorok have a very low tendency to chase, and it seems unlikely that they would attack wildlife. It is true that Komondorok are generally aggressive and protective dogs, but early social experience with a variety of people seems to alleviate excessively aggressive behavior towards humans (pers. obs.). Our dogs are either friendly to most people, or are shy of all humans except us.

Recommendations for Using a Komondor

The Komondor was developed by the early Hungarians as a flock guardian. It is a large breed with a heavy coat and predisposition for protecting property. No training as such is required to bring about guarding behavior, and probably no amount of training can make a flock guardian of a dog which lacks the intelligence, independence, and aggressiveness for the job. This does not mean, however, that Komondorok guard "instinctively" or that an individual dog does not require training to be useful. Rather it means that a dog can be an effective livestock guardian *if* it possesses the basic breed characteristics and *if* it is properly trained. Training and human influence are required in at least three areas: early socialization, obedience, and flock management.[1]

Training and rearing procedure should capitalize on two basic behaviors of the breed:

1. Komondorok are very conservative in nature. They adjust to the initial situation and react to change or novelty. This conservative nature is reflected in the traits we see in the breed: intelligence, stubbornness, aggressiveness, shyness, and strong habit formation.
2. Adult Komondorok have a low inclination to chase. Sheep accept them because they do not act like other dogs. Because they can stay close to the flock, Komondorok become attached to sheep (strong habit formation).

Early exposure to sheep and humans, if properly supervised, will likely eliminate many behavior problems in adult dogs. Exposure to sheep does not necessarily create an attachment, but rather acquaints the dog with the smell, sound, and behavior of sheep. Thus, it is not necessary to expose a 6- to 13-week-old puppy in order to achieve the desired result. In fact, puppies that are frightened or injured at this age can retain a lifelong aversion to sheep. On the other hand, dogs which are not exposed to sheep until maturity may become overly attached to humans.

We feel that a 6- to 10-month-old dog is ideal. It is less fearful and fragile than a puppy, yet young enough to transfer its affection to sheep. Also, its basic "personality" and physical structure are already evident. We recommend the following procedures in training a new Komondor of any age.

1. Place the dog with sheep immediately upon arrival at the farm or ranch and leave it there. The area should be large enough for the dog to move freely, but secure enough to prevent escape. It should include a sheltered place where the dog can retire from the sheep.
2. Choose the sheep to complement the dog's personality. We have found that yearling ram lambs do well with large, aggressive dogs, while bummer lambs are more suitable for small or shy dogs.
3. Supervise early contacts with sheep very carefully. Do not leave the dog unattended for long periods of time until it is clearly adjusted to the situation. Concentrate on building confidence by praising and rewarding desirable behavior.
4. Ignore (not punish) undesirable behavior unless it threatens the sheep. Chasing especially must be curbed since it can carry over into adulthood if learned as a puppy. Chewing ears and pulling wool are other traits which cannot be tolerated.
5. Give the dog at least basic obedience training. For the safety of sheep and humans the owner must have control over the dog. Obedience training also provides an opportunity for development of an affectionate dog-human bond. Work with the dog on a regular basis in the pasture with the sheep so that training becomes associated with the pleasure of the owner's company and with sheep.
6. As the dog matures and becomes accustomed to being with sheep, move it to situations which provide progressively more freedoms and opportunities for independent action. Continue to monitor it carefully, encouraging good behavior and showing displeasure at bad behavior.

[1] A brief guide to training a Komondor as a flock guardian is available from the senior author.

The breed's conservative nature can be exploited by leaving the dog with the flock throughout the production cycle. A working Komondor is not a pet. It should not be driven around in a truck, nor kept at the house or sheep camp. The tendency to guard an area can be enhanced by regularly walking the dog around pasture fences, feeding it only in the pasture, discouraging it from crossing fences, and firmly returning it to the pasture if it leaves. The dog's movements in the pasture can be influenced by the location of its food and water, the placement of shelters, and the activity of the sheep. Moving the sheep to another pasture, especially one unfamiliar to the dog, can upset the dog, and the owner may need to spend extra time familiarizing it with the new area. Komondorok eventually become accustomed to routine moves with the flock and can guard pastures of 200 ha or larger, but because of their strong site fidelity, they may be less adaptable to open range operations than are other guardian breeds.

Finally, the rancher should consider sheep behavior in response to the dog. Bands should be split or changed as infrequently as practical. Sheep should be left with the dog permanently, even during shipping and in feedlots. Many owners even allow their dogs access to lambing operations. Since Komondorok may have 6 to 10 or more years of service with a flock, it is possible within a few years for virtually every sheep to have known the dog since birth.

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Impact of Burning and Grazing on Soil Water Patterns in the Pinyon-Juniper Type

GERALD F. GIFFORD

Abstract

Soil water patterns were studied from June 1973 to February of 1977 in pinyon-juniper woodland, on pinyon-juniper areas chained and windrowed (grazed and ungrazed), and on pinyon-juniper areas chained with debris-in-place (ungrazed; burned vs. unburned). The pinyon-juniper woodland always had the least soil water, regardless of the season. Grazing did not affect soil water patterns on the chained with windrowing treatment. Burning of debris on the debris-in-place treatment had little impact on water the first year, but significantly more water was measured on the burned treatment at the beginning of the second year. Soil water patterns previously established between the unburned debris-in-place and ungrazed windrowed treatment changed in August, 1974, and the two treatments were equivalent for the balance of the study. Prior to August of 1974 the unburned debris-in-place treatment had always had more soil water than the ungrazed windrowed treatment. These changes were attributed to possibly milder winters with decreased snowfall.

As previously indicated by Gifford and Shaw (1973) and Gifford (1975), soil water patterns as influenced by vegetation manipulation practices have not received a great deal of attention in the pinyon-juniper *(Pinus edulis-Juniperus osteosperma)* type. No studies involving direct measures of soil water have been reported that relate effects of either grazing or burning of debris. Roundy et al. (1978) report that burning of pinyon-juniper in eastern Nevada is not expected to increase runoff or soil loss substantially on sites with coarse-textured soils. Buckhouse and Gifford (1976) found that initial impacts of grazing and burning on a chained pinyon-juniper site in southeastern Utah resulted in somewhat decreased infiltration rates. Long-term impacts were not defined, however.

The study discussed here represents an expansion of soil water investigations initiated in 1970 in southeastern Utah. The objective of this study phase was to determine the effect on soil water patterns of burning pinyon-juniper debris on a chained with debris-in-place site (no grazing), and of grazing on a chained and windrowed site. Concerning soil water patterns prior to the initiation of the grazing and burning aspects, Gifford and Shaw (1973) stated:

> Results. . .indicate the greatest moisture accumulation occurred under the debris-in-place treatment (as compared to woodland controls),. . .regardless of season. . . . The woodland had the least soil moisture throughout most of each year. Most moisture flux took place in the upper 60-to-90 cm of soil profile, with only minor changes occurring at greater depths. Differences in soil moisture patterns are due in part to differences in microclimates due to chaining, different rooting depths and length of growing season, mulching effect of litter on the debris-in-place treatment, and possible differences in snow accumulation.

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Site Description and Methods

The study site is within the Colorado Plateau about 70 km west of Blanding, Utah, in the N.E. 1/4 of S.W. 1/4 of T38S., R18E, near Coyote Flat at an elevation of about 2,150 m. The soils are derived from primarily sandstone and are of the Aridic Argiustolls-Typic Argiustrolls association. The soil profile depth is 1.5 m, and soil texture is primarily sandy loam with few, if any, rocks present. The pH ranges from 7.7 to 8.1. The canopy cover of mature juniper (500 trees/ha) and pinyon (200 trees/ha) averages 24 and 8%, respectively. Shrub cover is less than 1% and consists of big sagebrush. Bare ground and litter make up the balance. The bare ground category includes some cryptogam species present in the surface 3 cm of soil.

During the study period, the chaining-with-debris-in-place treatment at Blanding had a ground cover consisting primarily of 25 to 45% bare ground, 30 to 60% litter, and 12 to 20% crested wheatgrass. The chain-with-windrowing treatment had from 40 to 65% bare ground, 15 to 30% litter, and 17 to 25% crested wheatgrass cover.

Initial chaining treatments occurred in the fall of 1967. The windrowed treatments were drill seeded to crested wheatgrass *(Agropyron cristatum)* at 9.1 kg/ha and the debris-in-place treatment was broadcast seeded at the same rate to crested wheatgrass. The entire study area was then fenced to exclude livestock.

Secondary treatment (controlled burning) was applied to a portion of the debris-in-place treatment on September 5, 1974. A clean burn was produced with most of the fuel being consumed within 2 to 3 hours. Grazing remained excluded from this area.

During late May and early June, 1974, cattle were stocked on portions of the chained with debris windrowed treatment at the rate of 2 ha/AUM. This represented the first grazing since the 1967 chaining. Crested wheatgrass on the windrowed area was utilized 55% during the spring of 1974, 78% during the spring of 1975, and 66% during the spring of 1976. Utilization was determined at the close of each spring grazing period through clipping, using exclosure as control units.

Techniques for measuring soil water have previously been described (Gifford and Shaw 1973). The number of soil moisture access tubes monitored within each treatment included 15 in the woodland, 14 in the grazed windrow area, 6 in the ungrazed windrow exclosures, 9 in the burned debris-in-place area, and 6 in the unburned debris-in-place treatment.

Precipitation amounts received during the study period are given in Table 1.

Results and Discussion

Soil water patterns (Table 2 and Fig. 1 and 2) initially followed a trend similar to that already described by Gifford and Shaw (1973). The unburned debris-in-place treatment continued to evidence the greatest moisture accumulation among all treatments throughout the year until August of 1974. At that time, the soil moisture differences that had existed the previous 4 years between the

Table 1. Precipitation (cm) for Blanding study site.[1]

Date	Amount	Date	Amount
12-2-72 to 1-28-73	13.8	8-8-76	0.1
1-28-73 to 4-11-73	6.2	8-17-76	0.2
4-11-73 to 7-4-73	6.9	8-23-76	0.1
7-16-73	0.2	8-29-76	0.1
7-18-73	1.3	9-18-76	0.3
7-20-73	0.4	9-21-76	0.3
7-27-73	0.2	9-23-76	0.1
8-17-73	0.6	9-24-76	0.2
8-20-73	0.3	9-25-76	0.6
8-21-73	0.2	9-26-76	0.2
8-27-73	0.2	10-2-76	0.3
8-29-73	1.1	11-3-76 to 12-17-76	0.2
9-10-73	1.0	12-17-76 to 2-4-77	2.5
9-10-73 to 6-16-74	16.0		
7-15-74	0.2		
7-16-74	2.1		
7-18-74	0.4		
8-2-74	1.1		
9-14-74	0.4		
9-15-74	0.3		
9-24-74 to 6-14-75	27.0		
6-19-75	0.3		
7-9-75	1.4		
7-16-75	1.4		
7-26-75	0.1		
7-28-75	0.3		
7-29-75	1.6		
8-10-75	0.4		
8-12-75	0.4		
8-20-75	0.1		
8-21-75	1.1		
9-4-75	0.4		
9-15-75	0.5		
9-18-75	0.1		
9-27-75 to 6-6-76	10.2		
6-7-76	0.1		
7-9-76	0.2		
7-17-76	0.1		
7-18-76	0.1		
7-25-76	1.7		
7-26-76	0.6		
7-27-76	0.3		
7-30-76	1.4		

[1]Recording gages in operation from about June 10 to approximately October 1 of each year; storage gages operated during winter period.

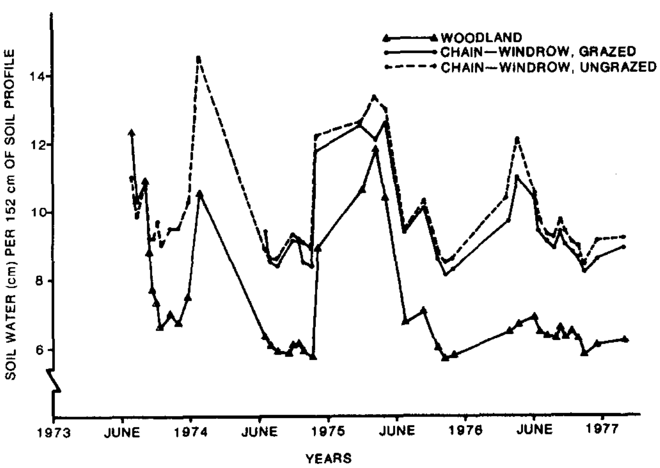

Fig. 1. *Soil water patterns in native pinyon-juniper woodland and in grazed and ungrazed chain with windrowing treatments.*

Table 2. Total centimeters of water per 152 cm of soil profile on various dates at Blanding study site.[1]

		Chain-windrow		Chain-debris-in-place	
Date	Woodland[2]	Grazed[3]	Ungrazed[4]	Burned[5]	Unburned[4]
6-21-73	12.31[a]		10.97[a]		14.97[b]
7-6-73	10.25[b]		9.82[a]		12.63[b]
7-19-73	10.81[a]		10.92[a]		13.79[b]
8-1-73	8.75[a]		9.19[a]		13.19[b]
8-16-73	7.67[a]		9.16[a]		12.70[b]
9-13-73	7.35[a]		9.66[b]		13.32[c]
9-24-73	6.63[a]		8.95[b]		12.69[c]
10-19-73	7.02[a]		9.48[b]		13.11[c]
11-24-73	6.72[a]		9.50[b]		13.70[c]
12-18-73	7.46[a]		10.30[b]		13.76[c]
1-26-74	10.47[a]		14.53[b]		—
6-16-74	6.38[a]	9.41[bc]	8.94[b]		11.31[c]
6-28-74	6.09[a]	8.52[b]	8.64[b]		10.90[c]
7-11-74	5.95[a]	8.40[b]	8.58[b]		10.53[c]
7-24-74	5.87[a]	—	—		10.71[b]
8-5-74	6.12[a]	9.07[b]	9.28[b]		10.61[b]
8-22-74	6.16[a]	9.10[b]	9.17[b]		10.41[b]
9-18-74	5.96[a]	8.51[b]	9.08[b]	11.20[c]	9.78[bc]
10-20-74	5.83[a]	8.41[b]	8.93[b]	10.84[c]	9.63[bc]
11-30-74	8.91[a]	11.78[b]	12.25[b]	14.23[c]	12.36[b]
3-37-75	10.63[a]	12.49[b]	12.55[b]	15.44[c]	15.08[c]
4-12-75	11.83[a]	12.09[ab]	13.27[bc]	14.49[c]	13.08[b]
5-10-75	10.39[a]	12.62[b]	12.95[b]	14.54[c]	13.65[bc]
6-24-75	6.75[a]	9.28[b]	9.41[b]	10.64[c]	9.66[bc]
8-24-75	7.07[a]	10.08[b]	10.27[b]	12.84[c]	11.25[b]
9-27-75	6.02[a]	8.61[b]	8.83[bc]	10.83[d]	10.13[cd]
10-11-75	5.68[a]	8.13[b]	8.50[b]	9.87[c]	9.02[bc]
11-22-75	5.81[a]	8.26[b]	8.57[b]	10.29[c]	9.38[bc]
4-3-76	6.52[a]	9.70[b]	10.39[b]	12.27[c]	10.70[b]
5-1-76	6.69[a]	10.95[b]	12.13[bc]	13.75[c]	11.92[b]
6-6-76	6.86[a]	10.36[b]	10.51[b]	12.57[c]	10.69[b]
6-20-76	6.48[a]	9.35[b]	9.73[b]	11.91[b]	10.24[b]
7-6-76	6.43[a]	9.10[b]	9.31[b]	11.88[c]	10.07[b]
7-25-76	6.33[a]	8.88[b]	9.15[b]	11.48[c]	9.50[b]
8-9-76	6.57[a]	9.39[b]	9.75[b]	12.01[c]	9.89[b]
8-23-76	6.51[a]	9.00[b]	9.42[b]	11.30[c]	9.72[bc]
9-5-76	6.46[a]	8.82[b]	9.07[b]	11.04[c]	9.34[b]
9-20-76	6.32[a]	8.64[b]	9.00[b]	11.17[c]	9.50[b]
11-3-76	5.81[a]	8.20[b]	8.45[b]	10.68[c]	9.12[bc]
12-17-76	6.08[a]	8.58[b]	9.12[b]	10.82[c]	9.02[b]
2-4-77	6.21[a]	8.94[b]	9.22[b]	11.25[c]	9.41[b]

[1]All values in same row with same superscript are not significantly different at .05 level of probability.
[2]No grazing since 1967.
[3]Crested wheatgrass utilized 55% during spring of 1974; 78% during spring of 1975; 66% during spring of 1976.
[4]No grazing since treatments installed in 1967.
[5]Burning in fall, 1974; no grazing since chaining treatments installed in 1967 and no grazing following burning.

ungrazed windrowed treatment and the unburned debris-in-place treatment disappeared, with comparisons remaining essentially the same throughout the balance of the study. The reason for this change is not clear, but it may have been related to winter climatic conditions and snowfall patterns. A series of mild winters with reduced snowfall and higher temperatures could have resulted in less of a differential catch in moisture between the windrowed and debris-in-place treatments. Transpirational losses from surviving pinyon-juniper trees on the debris-in-place treatment would also have increased.

Through the summer of 1973, the ungrazed windrowed treatment continued to display a pattern of increased soil water accumulation through the fall and winter periods. By late summer, however, its soil moisture patterns were similar to those found in the woodland. After 1973 the pattern changed, and in 1974, 1975 and 1976 soil water readings were always greater under the windrowed treatment than under the woodland. Most of the increased moisture accumulation occurred at soil depths below 60 cm.

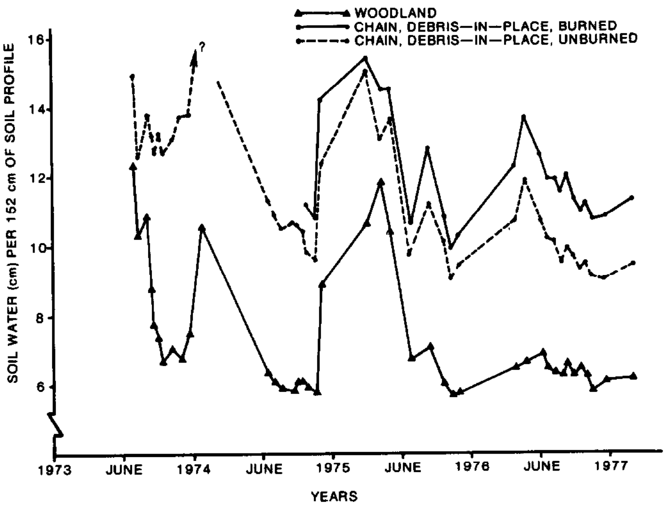

Fig. 2. *Soil water patterns in native pinyon-juniper woodland and in burned and unburned chain with debris-in-place treatments.*

Grazing did not affect soil water storage on the windrowed area, even though the crested wheatgrass on the area was utilized 55% to 78% each spring depending on the year. The lack of impact can probably be attributed to the initial low cover of the crested wheatgrass (maximum 25% canopy coverage). Under these conditions, grazing apparently does not alter evaporative conditions enough to modify soil water conditions.

Burning debris on the debris-in-place treatment had little effect on soil water accumulation the first year following burning. By the spring of the second year, however, significantly more moisture had accumulated under the burned treatment, and this trend continued throughout the remaining 17 months of the study. It would appear that the temporary effect of burning combined with seasonal growth (and transpiration) of the crested wheatgrass was sufficient to overcome the loss of debris piles (which reduce wind movement and provide mulch, both of which reduce the evaporation potential) on the burned area. In addition, as previously stated, the young pinyon and juniper trees that survived the chaining were transpiring year around on the unburned area. Assuming the burned sites behave in a manner similar to the windrowed area, however, this trend might easily be reversed with shifting climatic trends.

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Annual Grassland Response to Fire Retardant and Wildfire

JEANNE R. LARSON AND DON A. DUNCAN

Abstract

Diammonium phosphate (DAP), air-dropped in early autumn 1974 to contain a wildfire on the San Joaquin Experimental Range in California, applied high levels of nitrogen and phosphorus to foothill annual grassland. The DAP drop and fire provided 4 treatments for the study—unburned + DAP, burned + DAP, burned and unburned (control). In the first year both of the DAP treatments, with yields of more than 12,000 kg/ha produced twice that of the unburned (control). First-year forage yields for the unburned and burned plots were not significantly different. The second year the burned plot yielded almost twice that of the unburned. The second year, the unburned + DAP plot produced about 4200 kg/ha, the highest yield of all 4 plots, and significantly higher than the burned + DAP plots. Annual and seasonal weather patterns and soil moisture affected herbage composition more than treatments. Although forbs usually increase in annual grassland after fire, and nitrogen fertilizer favors grasses, grasses nonetheless dominated on all 4 treatments in the first year. Forbs were dominant the second year. The difference in relative percent composition of grasses and forbs was greater between years than between treatments.

Foothill annual grasslands and associated oak woodlands are California's largest and most important range types. The annual grasses and forbs germinate after the first effective rain in autumn, grow slowly through the winter, and then grow rapidly with warmer temperatures in early spring. In late spring plants quickly flower, set seed, and dry (Bentley and Talbot 1951). During late spring and summer, however, the vegetation, in addition to providing food and cover for domestic animals and wildlife, becomes a potential wildfire hazard.

Many studies have been done on the effects of burning oak woodland-grasslands. Vegetation grows more slowly the winter after burning (Hervey 1949), production is often less (Hervey 1949, Graham 1956), and composition changes (Graham 1956). Varying intensities of fires result in differential seed mortality (Burcham 1957) and alter chemical, physical, and biological properties of soils (Vogl 1974). Too, many soils of California are deficient in nitrogen (N), phosphorus (P), and sulfur (S), in varying degrees and combinations. Studies done on fertilization of these rangelands report that grass is stimulated by N fertilization (Duncan 1974, Martin and Berry 1970); P will often increase legumes if sufficient N is present (Heady 1975, Jones 1976, McKell et al. 1960); and the N produced by the legumes will, in turn, produce more grasses (Jones and Evans 1960). Of all the ecosystems they described, encompassing the entire United States, Garrison et al. (1977) said "...annual plants with their short life cycle and rather shallow root system, have probably shown the most consistent and profitable response to range fertilization."

To contain a wildfire, fire retardants are sometimes air-dropped on a burning woodland-grassland. One of these, diammonium phosphate (DAP), contains high levels of nitrogen and phosphorus. None of the studies cited earlier, however, has reported on the fertilizer effects of air-dropped DAP on California annual grasslands. Trade-offs between effects of fire and effects of fire retardant need to be quantified and evaluated. Other studies of air-dropped DAP have, thus far, concentrated on ecological problems (George et al. 1976). In the future, as increasing numbers of people move into the foothills, the benefits or disadvantages to range, wildlife, watershed resources and home protection need to be evaluated to obtain a more balanced assessment of this fire-fighting practice.

On October 5, 1974, a wildfire burned through woodland-grass across part of the San Joaquin Experimental Range in Madera County, 45 km northeast of Fresno, Calif. Aerially applied Phos-Chek XA[1] fire retardant (DAP) helped contain the fire. We took advantage of the fire and air drop of DAP to study their effects on forage yield, species composition, soil moisture, and grazing use by cattle. This paper reports the results of our study from October 1974 to May 1976.

Methods

The study area on the San Joaquin Experimental Range is at an elevation of 350 m and has been described as an "open, rolling slope" site (Bentley and Talbot 1951). Such sites have a long-term potential yield of about 2250 kg/ha/yr (Duncan and Woodmansee 1975). The slope is 5% with an easterly aspect. Scattered blue oak *(Quercus douglasii)*, buckbrush *(Ceanothus cuneatus)*, and granitic rock outcrops are seen in the general area (Fig. 1).

In addition to diammonium phosphate, DAP contains additives to reduce corrosion, enhance flow characteristics, and improve adherence to fuels. A water-soluble coloring agent in the retardant clearly delineated the affected area. Two parallel drops of DAP were made. Liquid released totalled 7728 liters (Henson, pers. commun.)[2] Each drop formed an elliptic pattern that covered a total area of about 0.4 ha resulting in an estimated application rate of 381 kg/ha N and 408 kg/ha P.

The wildfire burned about 5 ha before it was slowed by the DAP drop and contained by ground crews. A burned-only treatment area about 84 m^2 was selected downslope as near to the DAP drop as constraints of trees, rocks, and swales allowed; a control area of equal size was selected upslope. Plots were located in open grassland to minimize variance caused by shade from overstory, litter effects, and soil moisture. Plot locations were limited also to a minimum soil depth of 30 cm with no dung or indication of gopher activity.

Patterns of the wildfire and air-dropped DAP determined 3 of the 4 treatments. Combinations sampled included the control or unburned, unburned + DAP, burned, and burned + DAP. Ten 0.093 m^2 plots per treatment were sampled at random to estimate

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[1]Trade names and commercial enterprises or products are mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

[2]Roy Henson, air coordinator, California Department of Forestry, Sanger, Calif. 93657.

Fig. 1. *Open-rolling foothill-woodland with trees, shrubs, and granite outcrops.*

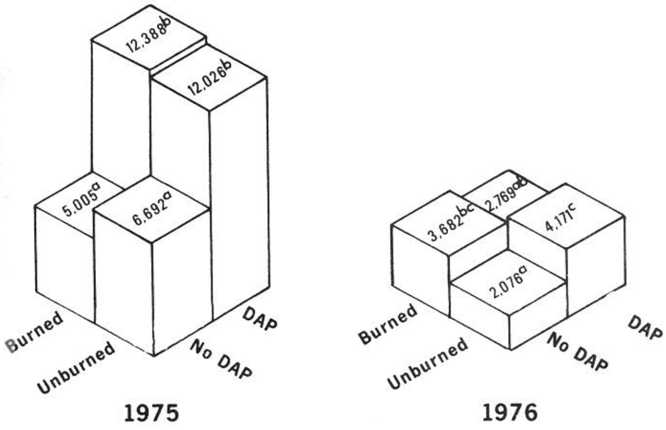

Fig. 2. *Herbage yield (kg/ha) 1975 and 1976 growing seasons. Treatment yields within years followed by a common letter are not significantly different (P<0.05).*

forage production. Data on yield were analyzed by a one-way analysis of variance and Tuckey's multiple range test.

Wire net cages were used to protect forage from grazing animals. At peak production these ungrazed plots were hand-clipped 1.3 cm above ground and yield calculated from air-dried weight of herbage. Percent species composition was calculated by hand-sorting the samples into 4 major species—soft chess *(Bromus mollis)*, ripgut brome *(B. diandrus)*, foxtail fescue *(Vulpia megalura)*, and broadleaf filaree *(Erodium botrys)*, and 2 groups— miscellaneous legumes and miscellaneous forbs (Table 1).

Soil water content was assessed by the gravimetric method at 3 depths (0–10, 10–20, and 20–30 cm) each month of the growing season. Two 5-cm diameter soil cores per treatment were taken at random just outside the caged sampling areas. Data were analyzed by analysis of variance. The official weather station at the San Joaquin Experimental Range headquarters about 1.6 km east of the study area provided weather records.

Forage utilization (yearlong grazing by cows and calves) was visually classified as light, medium, or close (Bentley and Talbot 1951).

Results and Discussion

Forage Yields

The unburned and burned treatments receiving DAP produced about 12,000 kg/ha of herbage in 1975, about twice that produced on the control and burned-only treatments (Fig. 2). Differences were statistically significant ($P<0.05$). No differences between burned and unburned treatments without DAP were observed.

The 1976 forage yield on control plots (2,076 kg/ha) was about 10% below the long-term mean and about 70% lower than production the year before. The burned and the unburned + DAP treatments both produced significantly more forage than the control. But production on the burned + DAP treatment did not differ significantly from the control or burned-only treatments (Fig. 2).

In terms of yield, therefore, an early fall application of air-dropped DAP resulted in much more forage the first year after treatment whether burned or unburned. The next year, however, carryover effects of DAP were detected only on unburned plots. Burning alone did not decrease production the first year, and second year yield on the burned-only plot was 1.8 times that on the control (Fig. 2).

In addition to treatment differences resulting from fertilizer and burning, weather during the study period obviously contributed significantly. Rainfall for the period September 1, 1974, to August 31, 1975, was 48.0 cm, an amount that compares to a 41-year mean of 48.5 cm. But because of colder-than-normal spring weather, growth of forage, especially forbs, was retarded for a longer-than-normal time. Unusually heavy, late spring rains (Fig. 3) were, however, early enough to stimulate the maturing plants so that forage yields were above average.

Rainfall for the 1976 growing season was below average, and a drought period with many frosty nights occurred in December and January. These harsh conditions not only retarded growth, but in many instances, killed the young plants on the shallower soils. Start of an adequate green grazing season was delayed until March

Table 1. Effect of wildfire and air-dropped DAP, alone and in combination, on species composition (% air-dry wt.) on California annual range land.

Year and treatment	Grasses			Forbs			Total	
	Bromus mollis	*Bromus diandrus*[1]	*Vulpia megalura*	*Erodium botrys*	Misc. legumes[2]	Misc. forbs[3]	All grasses	All forbs
1975								
Unburned	35	5	40	10	8	2	80	20
Burned	66	8	0	15	4	7	74	26
Unburned + DAP	23	38	19	19	0	1	80	20
Burned + DAP	33	42	21	4	0	0	96	4
1976								
Unburned	7	7	13	61	2	10	27	73
Burned	32	7	0	59	0	2	39	61
Unburned + DAP	3	8	13	37	0	39	24	76
Burned + DAP	7	3	21	67	0	2	31	69

[1]Includes minimal amount of red brome *(Bromus rubens)* and slender wild oats *(Avena barbata)*.
[2]*Trifolium* spp. and *Lupinus bicolor*.
[3]Primarily popcorn flower (*Plagiobothrys nothofulvus*) and smooth catsear (*Hypochoeris glabra*), except for unburned + DAP 1976, which was nearly all popcorn flower.

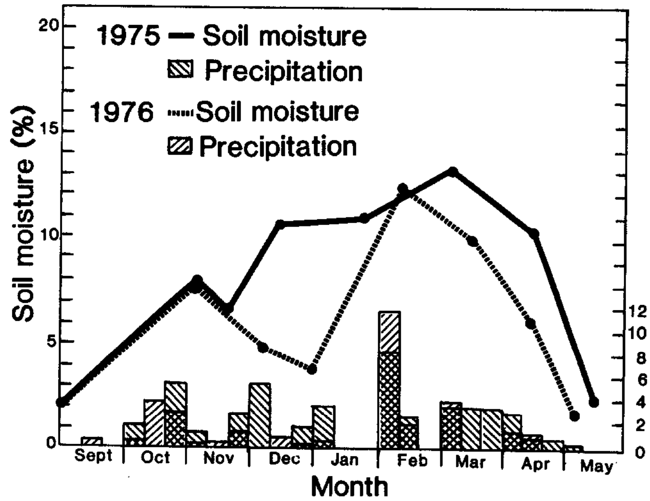

Fig. 3. *Percent soil moisture, 0–30 cm by month, and precipitation, as 10-day means, 1975 and 1976 growing seasons, San Joaquin Experimental Range.*

1. Late spring rains, however, stimulated the stressed plants and the season ended with average yields.

Species Composition

Instead of forbs being dominant the first year after the fire as expected (Graham 1956, Hervey 1949), grasses represented 80% of the air-dry weight (Table 1). The differences in percentages of grass species indicate either that fire increased the percent soft chess, or that foxtail fescue was inhibited by fire or was simply not present in the burned treatment. Foxtail fescue was equally abundant in the DAP treatments whether burned or unburned. Ripgut brome is known to respond to nitrogen fertilization and this was apparent in the first growing season in the DAP treatments. But ripgut brome did not respond to the carryover effects during the second growing season. Although DAP doubled yields, on both burned and unburned plots the first year following application, it did not appear to affect the grass-to-forb ratio. Legumes germinated but did not mature with the high nitrogen levels resulting from the DAP treatments.

Weather appears to have been the dominant variable influencing species composition. Colder-than-normal weather during the winter growing season favored grasses, and late spring rains decreased the competitive advantage forbs show over grasses when moisture is limiting (Talbot et al. 1939). Also, these late spring rains, coupled with the dense grass herbage, produced a microclimate with high relative humidity that favored an unidentified thin, white powdery mycelium, which reduced the number of filaree plants (pers. obs. Larson). Lush green foliage associated with postburn conditions may favor certain fungi and bacteria (Vogl 1974).

The second season after the first was a "forb year" for all treatments, with forbs comprising about 70% and grass about 30% of the forage crop. Filaree was by far the most abundant broadleaf plant except in the unburned + DAP treatment where popcorn flower *(Plagiobothrys nothofulvus)*, an early growing broadleaf that was heavily utilized by cattle, comprised 50% of the total forbs (Table 1). The winter drought definitely gave the forbs an advantage and, in combination with the long period of cold weather, resulted in many of the stressed grasses being frosted back or killed.

Production of native legumes on the San Joaquin Experimental Range has been shown to be positively correlated with late spring rains (Duncan and Woodmansee 1975). The differences between years on the unburned treatments also suggest this correlation. The fertilizer effect of N can also be a limiting factor in legume production (Table 1).

Utilization

Early in the 1975 green grazing season, observations suggest that the cows preferred grazing in the area that received DAP. The exact reasons for preferential grazing in areas that have been burned or fertilized have yet to be quantified, but such use frequently occurs (Heady 1975, Vogl 1974).

Close utilization was observed on the burned + DAP plots throughout both growing seasons. The unburned + DAP plots were utilized slightly less, perhaps indicating a positive interaction effect between burning and DAP as related to use. The burned plots were grazed at a moderate rate, only slightly more than the unburned.

The heavy utilization of the DAP areas probably affected the lack of fertilizer response the next year and seemed to delay the next green grazing season. Close utilization delays growth the next winter and reduces total yields in the spring (Bentley and Talbot 1951).

Fire retardant containing ammonium phosphate or sulfate should not cause toxicity problems (Dodge 1970). The close utilization of the bulk of the forage on the DAP areas did not produce toxic symptoms in cows and calves. This area, however, was only a small portion of the total grazing unit.

Differences in weather between the 2 years of this study were reflected in the results of soil moisture tests (Fig. 3). Each year a significant difference ($P<0.05$) in soil moisture was observed between the 0- to 10-cm depth and the lower depths for all treatments, except for the first and last samples of each season. But no significant difference was observed between depths of 10 to 20 cm or of 20 to 30 cm or between treatments. The differences, therefore, were in the upper 10-cm portion of the soil where from 75 to 80% of the roots of winter annuals are found (Duncan 1975).

Range Readiness

Annual range was considered ready for grazing without supplement when plants reached heights of 5 to 8 cm and plant growth was likely to stay ahead of cattle grazing. Range readiness occurred about February 11 on all treatments in 1975, except the burned area, which was not range ready until about 4 weeks later. The delayed growth in the burned-only area probably was related to the absence of litter that would have altered the microclimate near the ground and afforded some protection for the seedling plants from the colder-than-normal early growing season. Sampson (1944) found that forage is often green longer than normal on burned areas, but is shorter in height. The burned area developed slower phenologically, thereby producing a longer green season. Plant height was not reduced, however.

In 1976, all treatments were range ready by late February except the burned + DAP treatment, which was delayed until late March because of the abundance of broadleaf filaree that was semiprostrate as a result of cold weather.

Management Implications

This 2-year study demonstrates that a complexity of variables determines herbage yield and composition. Long-term studies by Duncan (1974) and Martin and Berry (1970) point out the need to evaluate annual grassland treatments for at least 10 years to obtain a realistic picture over time.

Reported responses (cited above) to fire and fertilizer in many areas of California have given similar results. Although our results apply only to the study area, they may be applicable to similar sites at other locations.

Results of this study suggest that prescribed fall fires should be studied as a means of increasing production on annual grasslands. A fall aerial drop of DAP markedly increased forage production on the annual grassland, but depressed native clover production for 2 years. Heavy preferential forage utilization on the fertilized areas probably reduced fertilizer carryover effects and subsequent production. Where no fertilizer was involved, the fall wildfire had little effect on forage yield or composition the first growing season after the fire, but yield was almost doubled the second year.

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Vegetative Response of Goldenweeds and Rayless Goldenrod to Simulated Mechanical Control

H.S. MAYEUX, JR.

Abstract

Topgrowth was clipped at heights which simulated mechanical disturbance from potted common goldenweed, Drummond's goldenweed, and rayless goldenrod plants in the glasshouse. Resprouting occurred within days after clipping at the soil surface or at heights of 2 to 8 cm, but 50 to 100% of the plants clipped at the soil surface died within 5 to 10 weeks after treatment. No plants survived after topgrowth was removed at 2 cm below the soil surface. Mortality, numbers of adventitious sprouts on survivors, and stem elongation rates of regrowth varied little with species or phenological stage at treatment. Generally, topgrowth was completely replaced during the first growing season after clipping. Mechanical treatments which leave even small portions of rooted stems, such as shredding, roller chopping, or chaining, would not be effective against these undesirable subshrubs. Some control should be possible with blades such as the "stacker rake" which shears stems at ground level. Mechanical practices which sever the woody taproots at a shallow depth (discing or shallow root plowing) appear to be the most promising for control of these subshrubs.

The goldenweeds (*Isocoma* spp.) and rayless goldenrod *(I. Wrightii)* are subshrubs which infest grasslands from the southern Texas coast [Drummond's goldenweed *(I. Drummondii)*] through the Rio Grande Plains [common goldenweed *(I. coronopifolia)*] to far West Texas, Arizona, and New Mexico (rayless goldenrod) (Correll and Johnston 1970). Common and Drummond's goldenweeds severely reduce forage production, and rayless goldenrod is highly poisonous to livestock (Sperry et al. 1965).

The feasibility of controlling these species with herbicides such as 2,4-D [(2,4-dichlorophenoxy) acetic acid] has been demonstrated, but responses to herbicide sprays are strongly dependent upon the occurrence of adequate rainfall to provide high availability of soil water prior to and during herbicide application (Mayeux et al. 1979, Mayeux and Scifres 1981, Sperry 1967). Use of herbicidal sprays in management of these subshrubs is limited by the low frequency of years with high rainfall during the growing season in the semiarid to arid regions where these species occur. Consequently, range managers have expressed interest in mechanical methods as alternatives to broadcast spraying.

Shredding of common goldenweed during March, April, May, or June was evaluated in a year of above-average rainfall on the Rio Grande Plains (Mayeux 1973). Because of adventitious sprouting, goldenweed canopy cover increased within 1 yr to 143% of pretreatment levels. Similar changes in canopy cover were also observed where Drummond's goldenweed was shredded in summer, but no specific information is available concerning the regenerative abilities of these subshrubs.

The objective of this research was to determine the vegetative responses of the 3 goldenweed species to removal of topgrowth at heights representative of varying intensities of mechanical disturbance. Mortality was of major interest, but the ability of survivors to replace topgrowth was evaluated as an indication of clipping effects on subsequent vigor.

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Methods

Plants of each goldenweed species were grown from seed in 25-cm diameter pots containing fine sandy loam soil (pH 7.4). Each pot contained a single plant. All plants were in their second growing season, with basal stem diameters of 1 to 2 cm. Potted plants were maintained in a glasshouse where temperatures varied with time of day and season from 20 to 34° C.

During July 1977, topgrowth was removed from potted Drummond's goldenweeds with pruning shears at heights of 1, 2, 4, or 8 cm above the soil surface. Other plants of all three species were clipped during the early vegetative growth stage in April 1978. Topgrowth was removed by cutting the stems at 2 cm below the soil surface, at the soil surface, or at 2, 4, or 8 cm above the soil surface. The soil was temporarily removed from around the stem base and upper taproot and the taproot was clipped to sever the plants below the soil surface. Roots were disturbed as little as possible, but some fibrous surface roots were severed. The soil was replaced to cover the cut end of the woody taproot.

The same five treatments were applied to other plants of each species during full bloom in the fall. Because of inherent phenological differences among species in the timing of anthesis, topgrowth was removed from rayless goldenrod in early September, from common goldenweed in late October, and from Drummonds goldenweed in mid-November 1978. Plants with topgrowth left intact were included in each experiment. All plants were watered as needed and provided with half-strength Hoagland's solution weekly.

Plants were individually observed daily for 2 weeks and then weekly for 10 weeks after topgrowth removal and numbers of new vegetative buds were recorded. Plants which failed to resprout were considered dead, and death of plants which occurred after resprouting was also recorded. Canopy heights of Drummond's goldenweed clipped in July were recorded 120 days after treatment, whereas heights of rayless goldenrod, common goldenweed, and Drummond's goldenweed clipped in April were measured in September, approximately 150 days after treatment. Canopy heights of plants clipped in the fall 1978 were measured at 90 days after treatment and again in July 1979, approximately 130 to 190 days after clipping, depending upon species. Daily stem elongation rates of regrowth were calculated by dividing the difference between canopy heights at the beginning and end of the study period by the number of days elapsed.

Ten replicates (plants) of each species and clipping treatment were arranged in completely random designs. Untransformed mortality data by treatment (clipping height), season, and species was compared with chi-square tests without expected frequencies

(Shefler 1969). Canopy heights and elongation rates by treatment or species were subjected to analysis of variance.

Results and Discussion

Goldenweed and rayless goldenrod plants clipped 2 cm below the soil surface did not resprout (Table 1). No evidence of bud initiation was found when the soil was carefully removed from around the taproots at the end of study. Essentially all plants of each species with topgrowth removed at or above the soil surface produced new vegetative buds on remaining stem tissues within 2 days after clipping, and new buds continued to appear for up to 5 weeks after clipping in April and throughout the winter and spring on plants clipped during full bloom. Plants clipped at the soil surface in April produced 2 to 10 buds; bud numbers increased with clipping height, with plants clipped at 8 cm bearing 51 to 80 buds. Numbers of buds produced by each species were similar (data not shown).

All buds on most plants clipped at the soil surface and those on some plants clipped at a height of 2 cm died at 6 to 10 weeks after treatment. Eventual mortality of plants clipped at the soil surface ranged from 50% of Drummond's goldenweed clipped during full bloom to 100% of rayless goldenrod plants clipped in April (Table 1). Mortality of each species was 10 or 20% greater when clipped at the soil line during vegetative growth in spring than during full bloom in fall, but chi-square analysis indicated no statistical effect of season of treatment.

Mortality of rayless goldenrod and common goldenweed was only 20 to 30% at 10 weeks after clipping at a height of 2 cm in either spring or fall, and no Drummond's goldenweed were killed by this treatment (Table 1). Mortality of Drummond's goldenweed was consistently less than that of the other two species following top removal at the soil surface or at 2 cm, although differences were slight (10 to 30%) and not significant ($\chi^2 = 1.83$). All Drummond's goldenweed plants survived clipping at heights from 1 to 8 cm in July. No mortality was observed after plants were clipped at 4 or 8 cm regardless of species or season (Table 1). Differences in mortality attributable to clipping height were highly significant ($\chi^2 = 89.3$ across all species).

Although adventitious buds appeared on stem bases within 2 days after clipping, elongation into stems did not begin until 2 to 3 weeks after topgrowth was removed in April or July. Initiation of stem growth on some plants clipped in the fall was delayed for up to 4 weeks.

Growth rates of Drummond's goldenweeds clipped in July varied little with clipping treatment. Average stem elongation rates ranged from 3.8 mm/day (1-cm clipping height) to 4.2 mm/day (4-cm clipping height) during the 120-day period of study. Calculated stem elongation rates ranged from 2.4 to 4.2 mm/day during the 5-month period after all 3 species were clipped in April (Table 2). Analysis of variance indicated no significant difference in growth rate attributable to species or clipping treatment, including untreated plants.

Table 1. Mortality of rayless goldenrod, common goldenweed, and Drummond's goldenweed 10 weeks after topgrowth was clipped above, at, or below the soil surface during vegetative growth in spring or full bloom in fall.

	Mortality (%) by species and season of treatment					
	Rayless goldenrod		Common goldenweed		Drummond's goldenweed	
Clipping treatment	Spring	Fall	Spring	Fall	Spring	Fall
None	0	0	0	0	0	0
4 or 8 cm height	0	0	0	0	0	0
2 cm height	20	30	20	20	0	0
Soil surface	100	80	80	70	70	50
2 cm below soil surface	100	100	100	100	100	100

Table 2. Mean stem elongation rates of adventitious sprouts during the 120-day period after topgrowth of rayless goldenrod, common goldenweed, and Drummond's goldenweed was clipped at various heights above the soil surface in spring.

	Stem elongation rate (mm/day ± S.D.) by species[1]		
Clipping treatment	Rayless goldenrod	Common goldenweed	Drummond's goldenweed
None	2.4 ± 0.3	3.8 ± 0.5	3.6 ± 0.7
8 cm height	2.7 ± 0.3	3.5 ± 0.3	2.8 ± 0.9
4 cm height	3.1 ± 0.5	3.7 ± 0.9	3.1 ± 0.3
2 cm height	3.1 ± 0.9	4.2 ± 1.0	3.4 ± 0.7

[1]Stem elongation rates of plants clipped at the soil surface are not reported because too few survived to constitute an acceptable sample. Standard deviations were calculated from a sample size equal to the number of plants surviving each treatment, usually 10.

Canopy heights of rayless goldenrod and common goldenweed plants clipped in April were equal to those of untreated plants when measured in September (Table 3). Regardless of clipping height, Drummond's goldenweed regrowth did not attain heights equal to untreated plants during the first growing season after top removal. Heights of clipped plants ranged from 42 to 46 cm when measured in September, whereas untreated Drummond's goldenweeds averaged 59 cm in height (Table 3). Drummond's goldenweed plants clipped at 1 to 8 cm heights in July were 45 to 49 cm tall when measured last in November. Untreated plants had grown to an average height of 62 cm.

Regrowth of plants which survived clipping during full bloom in the fall proceeded slowly during the winter months, averaging 0.8 to 1.1 mm/day, regardless of species or clipping height. Calculated growth rates during the period between the sampling at 90 days after clipping and the final sampling in July of the following year were comparable to those observed after clipping in April. Stem elongation rates of rayless goldenrod, common goldenweed, and Drummond's goldenweed averaged across all treatments were 2.1, 2.4, and 2.4 mm/day, respectively, during the growing season following top removal in the fall. Growth rates did not vary significantly with species or clipping height. Similarly, no differences were seen in canopy heights when last measured in July, although heights of rayless goldenrod tended to be less than those of other species, as was noted after topgrowth was removed in the spring.

Conclusions

The three species of *Isocoma* readily tolerated topgrowth removal at all heights above the soil surface. Competition with forage species where any of these shrubs occur would be reduced for several months at most by mechanical treatments which leave some stem bases intact, such as shredding or roller chopping. The relatively high mortality of rayless goldenrod (100%) and common goldenweed (50–80%) after clipping at the soil surface suggests that a shearing blade, such as the "stacking rake" commonly used in Texas for removal of woody brush (Fisher et al. 1973), should be evaluated for control of these subshrubs.

Table 3. Mean canopy height of rayless goldenrod, common goldenweed, and Drummond's goldenweed 5 months after topgrowth was clipped at various heights above the soil surface in April.

	Canopy height (cm ± S.D.) by species[1]		
Clipping treatment	Rayless goldenrod	Common goldenwood	Dummond's goldenweed
None	40 ± 4	58 ± 7	59 ± 9
8 cm height	43 ± 4	54 ± 4	45 ± 12
4 cm height	45 ± 7	52 ± 12	45 ± 4
2 cm height	43 ± 12	57 ± 12	46 ± 8

[1]Canopy heights of plants clipped at the soil surface were not reported because too few survived to constitute an acceptable sample. Standard deviations were calculated from a sample size equal to the number of plants surviving each treatment, usually 10.

Based on their response in the glasshouse, complete control would be expected with mechanical practices which sever the plants below the soil surface. Discing offers excellent potential for control of these small shrubs because it effectively severs roots at depths of 5 to 10 cm, and discing prepares a seedbed for revegetation. Encouraging results have recently been obtained by shallow rootplowing to a maximum depth of 20 cm during the dry summer months (personal communication, E.E. Martinez, County Extension Agent, Zapata County, Tex.); rootplowing at depths recommended for control of wood brush species, 25 to 40 cm (Fisher et al. 1973), is apparently ineffective against rayless goldenrod and the goldenweeds. Use of both discing and shallow rootplowing may be limited by the presence of the larger woody brush plants which commonly occur in association with the shrubs.

Rayless goldenrod and common goldenweed responded similarly to topgrowth removal during early vegetative growth in spring or during full bloom in fall, and the response of Drummond's goldenweed differed little in spring, mid-summer, or fall. The effectiveness of mechanical control practices is apparently not dependent upon phenological stage at the time of treatment.

In this study, clipping had no apparent adverse effect on the plants not killed. A single clipping did not reduce vigor as measured by growth rates or numbers of buds producing adventitious stems. Usually, topgrowth was completely replaced during the season of treatment or during the following season if plants were clipped at the end of the growing season.

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Impact of Burrowing Activity of the Bannertail Kangaroo Rat on Southern New Mexico Desert Rangelands

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Abstract

The impact of the burrowing activity of the bannertail kangaroo rat *(Dipodomys spectabilis)* on southern New Mexico desert rangelands was investigated. The study was conducted on black grama *(Bouteloua eriopoda)*, dropseed (*Sporobolus* spp.), and mesquite *(Prosopis glandulosa)* grassland vegetation types. Mound density was highest in the black grama type, somewhat intermediate in the dropseed type, and lowest in the mesquite-grassland type. The surface area occupied by mounds averaged 2% over all vegetation types in the study area. Plant cover was generally greater off mounds than on mounds. Annual plant cover was greater on mounds that off mounds, suggesting that activities of bannertail kangaroo rats promote the presence of annuals.

Bannertail kangaroo rats *(Dipodomys spectabilis)* occur in great number throughout southwestern United States (Stoddard et al. 1975). These rodents feed largely on seeds which they collect in cheek pouches and store in burrows beneath their mounds.

The bannertail kangaroo rat constructs large, conspicuous mounds, usually in open locations, although the rat occasionally takes advantage of protection offered by mesquite *(Propsopis glandulosa)*, creosotebush *(Larrea tridentata)*, and other desert shrubs (Monson and Kessler 1940, Holdenried 1957, Schroder and Geluso 1975). These mounds provide suitable conditions for the establishment and development of annual plants which may be less desirable for livestock production on rangelands (Holdenried 1957). Furthermore, on or near mounds, vegetation may be covered by soil from burrows, which prevent plants from completing their growth cycle (Fitch and Bentley 1949).

Kangaroo rats exert impacts on rangelands not only through direct forage consumption, but also through their burrowing activities. When evaluating game and livestock ranges for carrying capacity, grazing use, or rate of recovery, many researchers have paid little attention to the effect of the burrowing activities of these rodents on rangelands. Jaeger (1961) maintained that in areas where competition for forage exists between livestock and the bannertail, the large amount of food collected by the latter and stored in their mounds should be considered in estimating the number of cattle that may graze on such areas.

Hawbecker (1944) challenged the contention that kangaroo rat mounds are always undesirable. He concluded that the burrowing activity of the bannertail kangaroo rats appeared to benefit the local sheep industry in California through increased production of such palatable plant species as red-stemmed filaree *(Erodium cicutarium)*. However, Norris (1950) pointed out that Hawbecker referred only to annual forage and not to the more valuable perennial forage plants.

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There are no exact figures on the longevity of mounds, but Holdenried (1957) and Best (1972) stated that it took about 23 to 30 months for a characteristic mound to develop. Once abandoned, the mound collapsed within a month or so. A review of the literature reveals no information on the rate of vegetation invasion on the mounds.

Current information on the impact of the burrowing activity of the bannertailed kangaroo rat seems to be limited mostly to opinions based on qualitative observations. At present there is a concentrated effort by individuals and government agencies to control kangaroo rat populations. These control efforts are generally based on little ecological information. It thus seems necessary to obtain quantitative information that will supplement the currently available qualitative body of knowledge and enhance understanding of the impact of the burrowing activity of bannertailed kangaroo rats. This is especially true in the desert rangelands of southern New Mexico, where the species abounds.

Study Areas

The study was conducted early in the summer of 1979 on the New Mexico State University College Ranch, about 32 km north of Las Cruces. The climate is typical of southern continental interiors, with hot summers and mild winters. Annual precipitation averages nearly 22 cm, with the majority falling in July, August, and September. The area was described by Wood (1969). For this study, 3 distinct vegetation types were selected, one dominated by black grama *(Bouteloua eriopida)*, one by dropseed (*Sporobolus* spp.), and the third by mesquite-grassland. The grama type supported a few scattered individual mesquite and yucca *(Yucca elata)* shrubs, and several forb species and broom snakeweed *(Xanthocephalem sarothrae)* occurred on disturbed portions. The dropseed type was dominated principally by mesa dropseed *(Sporobolus flexuosus)* and sand dropseed *(Sporobolus cryptandrus)*. Individual yuccas occurred sparsely in this type as well as a few mesquite plants. Broom snakeweed occurred sporadically in fairly heavy stands on seemingly disturbed parts of this type. Annual and perennial forbs were also conspicuously scattered throughout the dropseed type, but even more so on disturbed areas. The mesquite-grassland type was characterized by broom snakeweed, mesquite, and dropseed as dominants. Throughout this type were a variety of annual and perennial forbs, with mostly annuals occurring on disturbed areas.

Methods

Density of the bannertail kangaroo rat mounds was determined by counting the mounds in 65 randomly located belt transects 12 m wide and 160 m long in each of the 3 vegetation types. The area of land disturbed by mounds was determined from the average of 2 perpendicular diameter measurements, one through the center along the longest axis and the other along the shortest distance across the mound (Mueller-Dombois and Ellenberg 1974).

Aerial plant cover measurements were made on mounds and off

Table 1. Bannertail kangaroo rat den density, size, percent active, and area disturbed in 3 vegetation types in Southern New Mexico.

Vegetation type	Mound density/ ha	Avg. area/mound (M^2)	% of area occupied by mounds	% of mounds active
Black grama	9.4 ± 6.9[1]	26.0 ± 4.07	2.5	38.0
Dropseed	7.6 ± 0.69	20.5 ± 2.43	1.6	32.0
Mesquite-grassland	2.5 ± 0.42	64.5 ± 7.93	1.6	21.8

[1]±Standard error ($P<0.05$)

mounds employing point sampling. The procedure consisted of randomly placing a 3-meter rod at 8 locations on a mound and at 8 locations at least 6 m from the periphery of the mound. At each placement of the rod, a thin steel wire was lowered vertically at 10 points (30-cm intervals) along the rod. Whatever the wire hit first was recorded. Aerial cover and composition was determined from plant contact. Differences between on mound and off mound percent composition of annual plants were tested using the paired *t*-test (Zar 1974).

Coefficients of similarity (Hansen and Beck 1968) were computed for the percent composition and cover of annual and perennials between mounds and off mounds for each type. Coefficients were also computed to assess the similarity of the percent composition of annual invading mounds in different types.

Results and Discussion

Mound Parameters

The highest mound density (9.4/ha) occurred in the black grama type, while the lowest (2.5/ha) occurred in the mesquite-grassland type (Table 1). The density of mounds in the dropseed cover type was intermediate. Analysis of variance showed a significant difference ($P<.001$) among the mean numbers of mounds on the three cover types. Fisher's protected least significant difference (LSD) procedure for pairwise comparison of means (Ott 1977) indicated that all the means differed significantly from each other ($P<.005$). Data collected in 1960-1963 by Wood (1969) on the same area as this study showed that the density of the bannertail kangaroo rat mounds in the black grama grassland was 10.1/ha using the quarter method, and 11.4/ha using the transect method.

Wood (1969) determined the size of denuded areas on and around mounds and established that 10.6% of the black grama range supported little perennial forage. This study revealed that 2.4% of the black grama range was occupied by mounds. The discrepancy between Wood's (1969) estimate of area occupied by mounds and that determined in this study was not due to a change in density, but rather to the size of individual mounds. Wood (1969) found that the average area disturbed was about 105 m^2, nearly 4 times larger than that measured in this study.

The difference between the early 60's and 1979 may be explained by foraging behavior of the bannertail and precipitation patterns. During the 1950's a serious drought had reduced and eliminated much plant cover on the College Range. In 1960 the grasslands were still recovering from the drought, and forage plants were scarce, which forced the bannertail to forage over a large area to meet dietary needs. In the 4 years prior to and including 1979, precipitation was average or above average, which assured adequate forage for the bannertail and reduced the area physically disturbed.

Best (1972) and Schroder and Geluso (1975) reported that, in

Table 2. Aerial cover (%) and composition of (%) of plant species found on and off bannertail kangaroo rat mounds in 3 vegetation types in southern New Mexico.

	Black Grama				Dropseed				Mesquite-Grassland			
	On-mound		Off-mound		On-mound		Off-mound		On-mound		Off-mound	
Species	Cover	Comp	Cover	Comp	Cover	Comp	Cover	Comp	Cover	Comp	Cover	Comp
Annuals												
Amaranthus retroflexus	—	—	—	—	0.1	0.6	—	—	0.2	0.7	—	—
Aphanostephus ramoissimus	12.0	55.6	14.0	25.8	12.1	53.8	12.2	28.4	2.5	7.9	1.0	2.9
Chenopodium spp.	—	—	—	—	0.1	0.3	—	—	0.1	0.2	—	—
Cryptantha crassisepala	0.4	1.8	0.4	0.7	0.8	3.7	0.7	1.7	0.8	2.7	0.2	0.4
Dithyrea wislizeni	0.8	3.6	0.1	0.3	2.4	10.8	0.5	1.1	4.5	14.5	0.8	2.4
Lesquerella gordonii	3.3	15.4	1.6	3.1	0.4	1.7	0.1	0.3	—	—	—	—
Machaeranthera tanacetifolia	—	—	—	—	0.1	0.6	—	—	—	—	—	—
Mentzelia albicaulis	0.1	0.6	0.3	0.5	0.3	1.1	0.1	0.2	1.2	3.9	0.3	0.7
Nama hispidum	—	—	0.8	1.6	0.2	0.8	1.4	3.2	2.8	9.2	2.3	6.6
Plantago patagonica	—	—	0.2	0.3	—	—	—	—	—	—	—	—
Salsola kali	2.0	9.5	0.4	0.7	1.9	8.5	T	0.1	3.2	10.4	—	—
Xanthocephalum sphaerocephala	—	—	—	—	—	—	—	0.1	0.2	0.7	2.1	
Total annuals	18.6	86.5	17.8	33.0	18.4	81.9	15.0	35.0	15.4	49.7	5.3	15.1
Perennials												
Aristida longiseta	—	—	0.2	0.3	—	—	0.2	0.4	—	—	0.2	0.6
Bouteloua eropida	—	—	18.7	34.5	—	—	—	—	—	—	0.3	0.7
Erioneuron-pulchellum	1.0	4.7	0.8	1.4	1.0	4.2	1.6	3.7	—	—	0.4	1.0
Sporobolus spp.	0.6	2.9	7.8	14.3	1.5	6.8	19.8	46.0	1.3	4.1	10.4	29.6
Baileya multiradiata	—	—	0.4	0.7	0.1	0.6	0.4	0.8	0.5	1.7	—	—
Cassia bauhinoides	0.1	0.6	0.1	0.2	—	—	0.2	0.4	—	—	—	—
Croton corymbulosus	—	—	0.8	1.4	0.1	0.6	1.3	2.9	—	—	—	—
Ephedra spp.	—	—	0.1	0.2	—	—	—	—	—	—	0.2	0.6
Hymenopappus robustus	—	—	0.4	0.7	0.4	1.7	0.4	1.0	—	—	0.1	0.1
Opuntia spp.	—	—	—	—	—	—	0.1	0.2	—	—	—	—
Prosopis glandulosa	—	—	0.2	0.3	—	—	0.5	1.1	2.2	6.9	5.7	16.2
Psilostrophe tagetinae	—	—	0.1	0.2	—	—	—	—	—	—	—	—
Solanum elaeagnifolia	0.3	1.2	—	—	—	—	T	0.1	0.5	1.7	0.2	0.6
Sphaeralcea coccinia	—	—	—	—	—	—	—	—	0.7	2.2	0.6	1.6
Xanthocephanlum sarothrae	0.9	4.1	6.8	12.6	0.5	2.2	2.6	6.1	10.0	32.5	11.6	32.8
Yucca elata	—	—	0.1	0.2	0.5	1.7	0.5	1.1	0.1	0.5	0.2	0.6
Zinnia grandiflora	—	—	—	—	—	—	0.1	0.3	—	—	0.2	0.4
Total perennials	2.9	13.5	36.5	67.0	4.1	17.8	27.7	64.1	15.3	49.6	30.1	84.8

Table 3. Coefficients of similarity for cover and composition comparing on-mound with off-mound vegetation.

	Annuals		Perennials	
	% similarity of:		% similarity of:	
Vegetation type	cover	composition	cover	composition
Blackgrama	80.0	52.1	12.2	21.4
Dropseed	81.7	55.8	25.8	39.1
Mesquite-grassland	45.0	40.7	63.4	68.7

general, the bannertail prefers open grassland and mixed grass-shrub types. In this study, both the black grama and dropseed grasslands were interspersed with yucca and a few mesquite shrubs. Findley et al. (1975) stated that grasses make up an important part of the diet of the bannertail kangaroo rat, and that the species is abundant where grasses such as *Bouteloua* spp. and tobosa *(Hilaria mutica)* are common. The observed difference in mound density between the 2 grasslands is possibly due to differences between physical heights of black grama and dropseed since some mesquite and yucca were present on both types. Moreover, the results of this study seem to suggest that the bannertail kangaroo rat is a climax species in the area studied.

The low mound density in the mesquite-grassland type was possibly a result of invasion by shrubs such as mesquite and broom snakeweed, as is shown by a low percentage (21.8%) of active mounds. Monson and Kessler (1940) excavated mounds of the bannertail kangaroo rat in Arizona and New Mexico and found mesquite beans among the stored food material. Wood (1969) also excavated mounds of the bannertail on the College Ranch and found, among other things, seeds of broom snakeweed. Reynolds (1950), after studying Merriam's kangaroo rat in Arizona, stated that when seed is available a large volume is stored undermounds. These seeds left in the ground are in a more favorable environment for germination and establishment than are those lying on top of the ground. Reynolds and Glendening (1949) reported that Merriam's kangaroo rat collects mesquite seeds as a preferred food item and concluded that this rat is a factor in mesquite propagation on southern Arizona rangelands.

Therefore, in southern New Mexico the bannertail kangaroo rat may be partly responsible for the spread of mesquite and broom snakeweed. Apparently, the propensity of the bannertail to store seeds not only limits the potential production of perennials but also decreases the amount of habitat suitable for the rat itself.

The average area of mounds in the black grama and dropseed grasslands were similar and relatively small, compared to the average area of mounds in the mesquite-grassland (Table 1). This is probably because most mounds in the mesquite-grassland type were observed to be old, without well-defined edges. Thus the diameters measured on these old mounds possibly included the denuded area around mounds, which normally represent the foraging area of the bannertailed kangaroo rat.

Vegetational Cover and Composition

The on-mound and off-mound cover and botanical composition for the respective vegetation types are shown in Table 2. In all 3 vegetation types, the percent composition of annual plants was significantly higher on mounds than off mounds. Coefficients of similarity were 52.1, 55.8, and 40.7%, respectively, for black grama, dropseed, and mesquite-grassland types, which suggested that species composition of annuals on mounds had limited similarity to that off mounds (Table 3). This implies that the environment on the mounds is suitable for the growth of annual plants, which agrees with previous research observations (Hawbeck 1944 and Holdenreid 1957).

Conversely, the botanical composition of perennials was lower on mounds than off mounds in all 3 types (Table 2). The coefficients of similarity between on mound and off mound composition of perennials were, respectively, 21.4, 39.1, and 68.7% for black grama, dropseed and mesquite-grassland (Table 3). The coefficients for the 2 grasslands reflect strong dissimilarity; that for mesquite-grassland suggests a tendency toward similarity. This latter situation can be partly explained since most of the mounds in this cover type were no longer occupied, and there had been considerable mesquite and snakeweed invasion on these mounds.

Aerial plant cover was generally higher off mounds than on mounds (Table 2). The low percent cover on mounds was probably due to the fact that kangaroo rats eliminate vegetation after it has started to grow by covering it with soil from burrows, and by cutting and then carrying plant parts into the mounds (Fitch and Bentley 1949). However, the percent of annual cover was very similar between on and off mounds in the black grama and dropseed types, while it tended to be dissimilar in the mesquite-grassland type (Table 3).

The percent aerial cover of perennial plants was generally higher off mounds than on mounds. Similarity coefficients were very low for the 2 grasslands types (Table 3). Generally, important perennial grasses such as black grama and dropseed were either absent or comprised very little of on-mound vegetation (Table 2).

Percent cover and composition of annuals and perennial on active and inactive mounds were calculated for each vegetation type (Table 4). Generally, one would expect the total cover on active mounds to be lower than that on inactive mounds because of disturbance from burrowing and foraging activities of the bannertail and probably due to lack of a good seed source. This appeared to be the case in the black grama type. However, total cover figures on active and inactive mounds on the other 2 types were similar. No plausible explanation could be found for this apparent anomaly.

Coefficients of similarity were calculated to determine the degree of similarity in the species composition for the three cover types. The values were 54.0% for black grama vs dropseed, 35.2% for black grama vs mixed shrub-grassland, and 47.0% for dropseed vs mixed shrub-grassland. On the basis of these figures it was established that the 3 cover types were different from one another.

Coefficients of similarity were calculated to determine the degree of similarity in the percent composition of annuals on mounds among vegetation types. The values were 79.5% for black grama vs dropseed, 34.2% for black-grama vs mixed shrub-grassland 49.1% for dropseed vs mixed shrub-grassland. It appears that the on-mound species compositions of annuals in the two grassland cover types were similar. However, the composition of annuals on mounds in the grassland types seems to be different from that of the mixed shrub-grassland (Table 2). This difference between on-mound composition of annuals on the grasslands and mesquite grassland was probably due to the invasion of mesquite and broom-snakeweed on the mounds in the mesquite-grassland.

Table 4. Percent cover and composition of annual and perennial plants on active and inactive mounds in the black grama, dropseed, and mixed mesquite-grassland cover types.

	Active Mounds				Inactive Mounds			
	Annuals		Perennials		Annuals		Perennials	
Vegetation type	Cover	Comp	Cover	Comp	Cover	Comp	Cover	Comp
Black grama	17.4	84.0	3.3	16.0	34.6	90.0	2.7	9.2
Dropseed	16.0	70.0	6.9	29.9	18.9	84.9	3.4	14.8
Mesquite-grassland	17.4	56.3	13.4	43.8	15.1	50.5	14.8	49.6

Conclusions

1. The bannertail kangaroo rat prefers open grasslands interspersed with a few shrubs, but shows greatest preference for areas with short grass. In the area studied, the bannertail seems to be associated mainly with climax grassland (black grama). Grasslands with heavy mesquite infestation seem to be the least suitable habitat.

2. Burrowing and foraging activities by the bannertail affected the composition and cover of plants growing on mounds. Annuals were more commonly found growing on mounds, while the reverse was true for perennials. This substantiates the contention that activities of the bannertail kangaroo rat encourage development of annual plants and can thus lower perennial plant production on southern New Mexico desert rangelands.

3. The range management implications of the results of this study are complicated by the fact that very little is known about the biology and ecology of the bannertail. Moreover, the apparent association with climax grassland might limit any attempt to control or restrict the population. The problem is further aggravated by lack of information on how many rats actually construct each mound, and how long it takes an abandoned mound to be revegetated by desirable perennial grasses in southern New Mexico.

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Mortality of Bitterbrush after Burning and Clipping in Eastern Oregon

ROBERT G. CLARK, CARLTON M. BRITTON, AND FORREST A. SNEVA

Abstract

Bitterbrush plants were burned or clipped to 5 cm, during fall and spring, under different soil moisture conditions on 2 sites in eastern Oregon. Treated plants on the *Juniperus/Artemisia*-Purshia site had an erect growth form while those on the *Pinus-/Purshia* site were a loq-growing, decumbent form. Sprouting after treatment was similar for the 2 sites and associated forms. Burning resulted in greater mortality than clipping. Spring treatments had less mortality compared to fall treatments. Artificially watering plants did not result in a substantial reduction in mortality. Over-winter mortality of sprouts reduced the number of bitterbrush plants alive in the second growing season.

A publication summarizing recent literature on bitterbrush *(Purshia tridentata)* revealed that only about 10% of the citations alluded to bitterbrush response to fire (Clark and Britton 1979). The literature indicated that bitterbrush is a desirable shrub but may not be compatible with currently popular use of fire as a vegetation management tool. Response of bitterbrush to burning has been variable. In eastern Idaho it sprouted frequently but inversely with burn intensity (Blaisdell 1950, 1953). In central Oregon, Driscoll (1963) suggested that sprouting was related more to surface soil texture than burn intensity. Sprouting after wildfires was also variable in California. For example, in 5 of 13 wildfires at least 5% sprouting occurred, with a maximum of 25% (Nord 1965). In northern and central Utah limited sprouting occurred after wildfires (Blaisdell and Mueggler 1956). Daubenmire (1970) noted that bitterbrush was nearly always killed by wildfires in the steppes of Washington. Hormay (1943) stated that vast areas of bitterbrush have been destroyed by fire, and Billings (1952) contended that bitterbrush in the western Great Basin was permanently eradicated by fire.

Mechanical top removal appears less damaging to bitterbrush than burning. Ferguson (1972) recommended removing 33% and 50% of the canopy to stimulate growth. Mueggler and Blaisdell (1958) reported that rotobeating and railing was less damaging than burning. Blaisdell and Mueggler (1956) burned or severed bitterbrush plants 5 cm above ground level monthly, May through October. They found 50% and 72%, respectively, of burned and severed plants sprouted, with spring treatments the least damaging. Some plants did not sprout until 13 months after treatment.

Since bitterbrush at different locations may exhibit variable genetic traits, isolating specific factors which control sprouting is difficult. However, certain environmental parameters have been implicated in sprouting. This study was conducted to evaluate some environmental parameters which may be responsible for the variation in bitterbrush response to burning and clipping.

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Study Areas and Methods

Two areas representing different plant communities were selected for study. Site I was located 30 km northwest of Burns, Ore., at 1,555 m elevation. Characteristic vegetation is the *Juniperus/Artemisia-Purshia* association (Fig. 1) described by Driscoll (1964). Bitterbrush growing on this site does not layer and is similar to the columnar forms described by Alderfer (1977). Soils are Lithic Zerollic Paleargids over silica and limestone coated fractured bedrock (Lindsay et al. 1969).

Site II was located 42 km north of Riley, Ore., at 1,585 m elevation. Characteristic vegetation on Site II is similar to the *Pinus ponderosa/Purshia tridentata* (Fig. 2) association described by Daubenmire and Daubenmire (1968). Bitterbrush on this site is a low growing, decumbent form that infrequently layers. Soils are Lithic Argixerolls overlying rhyolite (U.S. Forest Service 1977). Soil texture on both sites is similar (Clark 1979). Both soils are shallow, averaging about 36 cm to bedrock.

Both sites were located with the High Lava Plains physiographic province described by Franklin and Dyrness (1973) on the western fringe of the Great Basin. Average annual precipitation on both sites is similar, about 30 cm. Most of the precipitation occurs as snow during the winter months. During the study period snow persisted about 2 weeks longer on site II than on site I due to the canopy of ponderosa pine. Bitterbrush phenological development correspondingly was initiated about 2 weeks later on site II than on site I.

A total of 80 bitterbrush plants on each site were randomly selected with 10 assigned to each of 8 treatments: fall clip, fall clip then water, spring clip, fall burn, fall burn then water, water then fall burn, spring burn, and control. Treatments applied later than August 1 were considered fall treatments because aerial growth had stopped and seeds had been dispersed although leaf abscission had not occurred. Fall treatments were applied during early August 1977 when 97% of the achenes had abscised. Spring treatments were applied in late March on site I and mid-April 1978 on site II when the first leaf on each fascicle was approximately 30% expanded. Earlier spring treatment was prohibited by snow cover.

Air temperature, relative humidity, and wind speed during burn treatments were determined with a battery operated fan psychrometer and a hand-held anemometer (Table 1). To produce uniform intensity on all burn treatments, plants were burned individually in a plant burner (Britton and Wright 1979). The burner was calibrated to attain a soil surface temperature of about 260° C at 45 seconds. Water treatments were applied 24 hours prior to, or immediately after burning to simulate a 5-cm precipitation event. Water was applied as a fine mist with a calibrated positive displacement pump. With the post-burn water treatments, water was applied 1 minute after the flame subsided. Water was restricted to approximately the area of the plant burner by circular metal rings (110 cm diameter) embedded in the soil surface. Soil moisture was measured gravimetrically at the time of treatment. Clipped plants were severed approximately 5 cm above the soil surface to ensure removal of all photosynthetic material.

Fig. 1. *Erect bitterbrush growth form on site I. Light colored shrub in foreground is* Artemisia tridentata.

Treated plants were observed monthly on each site during the summer of 1978 and in June of 1979. Each plant with visible sprouts was recorded. The number of live plants in each of the 8 treatments was subjected to Chi-square analysis to detect statistical differences.

Results

Sprouting of bitterbrush on site I and site II was similar and percent survival values could not be separated ($P<0.10$) between sites regardless of treatment. Therefore, data were combined for site I and site II. None of the unwatered fall-burned plants sprouted (Fig. 3). Spring-burned plants exhibited a peak in sprouting by August of the first growing season. However, mortality of sprouts over-winter reduced the proportion of plants alive to 10% by June of the second growing season.

Clipped plants sprouted more frequently than burned plants. Sprouting response through time was similar to spring-burned plants with peaks occurring in July and September for fall- and spring-clipped plants, respectively. Over-winter mortality was substantial with 40% of spring-clipped plants remaining alive compared to 30% for fall-clipped plants. Regardless of treatment, spring treated plants responded better than fall treated plants.

Plants watered either before or after burning responded poorly (Fig. 4). Water treatments increased the soil moisture in the surface 5 cm to approximately 14% compared to an average of 5% soil moisture adjacent to unwatered plants. Some watered plants did sprout as compared to no sprouting of unwatered plants. However, only 5% of the water-then-fall-burn plants remained alive by June of the second growing season. Fall clip-then-water plants responded similarly to fall clip plants through the first growing season. Mortality over-winter was much greater for the watered plants as contrasted with the unwatered plants.

Discussion

The anticipated beneficial effects of high soil moisture on fall-burned plants were not realized. Plants watered immediately after burning were expected to sprout since: (1) woody skeletons were not consumed, (2) heat was removed within 1 minute by water, (3) soil moisture approached 14%, and (4) other work has indicated that fire extinguished by water resulted in increased sprouting (Blaisdell and Mueggler 1956). With spring-burned plants, sprouting was increased. This could have resulted from soil moisture. Spring soil moisture was 27% to 30%, two-fold greater than with pre-watered fall burns. Also, air temperature was lower with the spring burns at 10° to 12° C.

Timing of fall treatments may be critical. Nord (1965) reported that more than 50% of plants clipped in late fall and winter sprouted, but no sprouting occurred on a similar site when plants were clipped during late summer and early fall; the difference was attributed to soil moisture.

Growth form also could have been important. Although plants on neither site were layering at time of treatment, all burned plants that sprouted on either site did so from bud masses near the axils of existing branches close to the soil but not from callus tissue on the stem as reported in Idaho (Blaisdell and Mueggler 1956).

Clipped plants displayed a response similar to burned plants

Fig. 2. *Decumbent bitterbrush growth form on site II. Bitterbrush density is greatest in* Pinus ponderosa *openings and is reduced where pine regeneration is well established.*

with respect to growth form. The decumbent form sprouted more frequently than the erect form especially with spring treatment. Other studies reporting clipping response of bitterbrush have shown differing seasonal effects and that partial top removal actually stimulated twig production (Garrison 1953, Ferguson and Basile 1966, Ferguson 1972). These reports did not present a detailed growth form description.

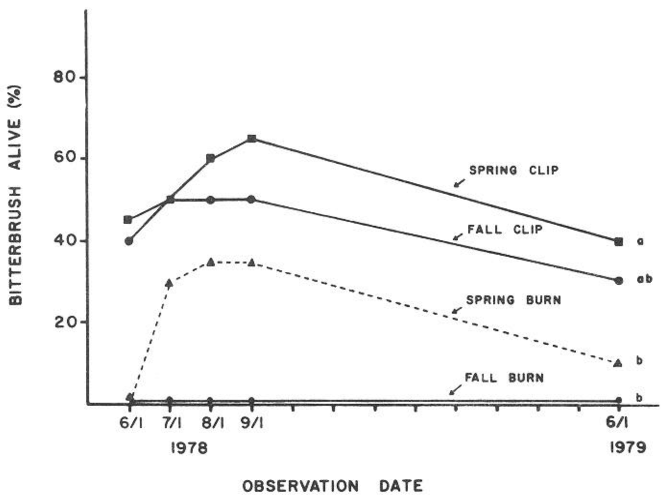

Fig. 3. *Percent bitterbrush plants alive for spring and fall, clip and burn treatments in eastern Oregon. Letters following values at final observation data indicate significant differences (P<0.10).*

Sprout mortality presents another important consideration. Even with good sprouting response, over-winter sprout mortality following 1 growing season can further reduce bitterbrush populations. These data indicate that this reduction can be substantial. In southern Idaho a similar trend in sprout mortality was observed where 33% of he burned plants and 21% of the clipped plants had died within 16 months of treatment (Blaisdell and Mueggler 1956).

Bitterbrush treated or injured mechanically recovers rapidly on

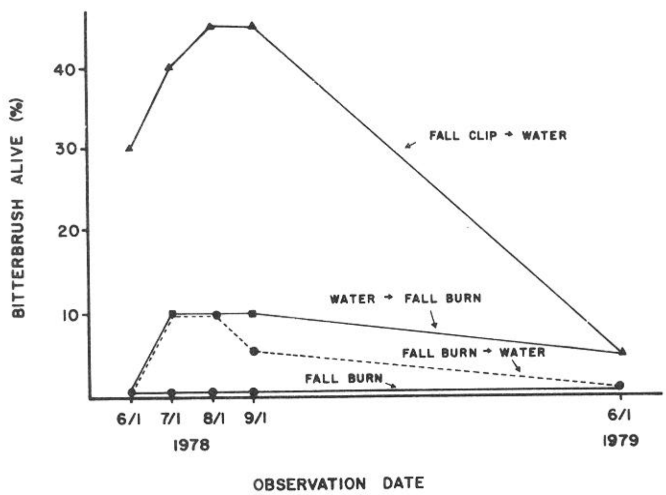

Fig. 4. *Percent bitterbrush alive for fall treatments in eastern Oregon. On final observation, treatments were not significantly different (P<0.10).*

Table 1. Weather conditions during 4 burning periods on 2 bitterbrush sites in eastern Oregon.

	Fall burns		Spring burns	
	Site I	Site II	Site I	Site II
Treatment date	8/3/77	9/5/77	3/30/78	4/13/78
Temperature (°C)	29	27	12	10
Relative humidity (%)	14	22	69	36
Wind speed (km/hr)	<8	< 8	< 8	< 8

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some sites (Ferguson and Basile 1966, Edgerton et al. 1975, Stuth and Winward 1976), although severity of treatment and site conditions affect recovery. Recovery following burning, however, is somewhat paradoxical. Data from this study confirms most reports which suggest that bitterbrush does not sprout abundantly after fire, yet fire creates litter-free sites necessary for germination of rodent-cached seed (Sherman and Chilcote 1972). Since most bitterbrush reproduction is from seed (Daubenmire and Daubenmire 1968, West 1968) rather than from sprouts or layering, reestablishment on burned areas should be enhanced by leaving intact an ample seed source or by planting.

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Trampling Damage by Cattle on Northern Idaho Forest Plantations

D.M. EISSENSTAT, J.E. MITCHELL, AND W.W. POPE

Abstract

The effects of cattle trampling in a Douglas-fir plantation the first year after planting were assessed. Trees partially girdled due to trampling were much more likely to die than untrampled trees ($\alpha = .0001$). An average of 19% of the trees in the plantation had been trampled; however, the damage was uneven due to clumped cattle distribution. The results reflect the hazard of grazing Douglas-fir plantations in the northern Rockies during the first year after establishment.

In the northern Rockies, forest managers are concerned with the potential deleterious effect that livestock grazing has on tree regeneration failure. Transitory ranges are defined here as forested areas that are only suitable for grazing over a temporary number of years following logging, fire, etc., before the overstory canopy closes in, thereby intercepting the light needed for forage production. Several workers have reported significant mortality from high intensity or poorly controlled livestock grazing (King et al. 1978, Hedrick and Keniston 1966, Young et al. 1942). These workers also found properly controlled grazing to be compatible with tree regeneration. There is confusion, however, on the kinds of grazing systems that do not hinder regeneration of different tree species in different regions.

In the Southeast, slash pine *(Pinus elliotti)* is very resistant to livestock damage (Lewis 1980a). Pearson et al. (1971) found that neither light nor moderate grazing affected slash pine survival for the first 5 years after planting. Heavy grazing did result in 306 fewer trees per ha (124 per acre), but losses were fairly well distributed. The authors concluded that slash pine plantations can be heavily grazed the first year if cattle are witheld until June.

In the Northwest interior, trees appear to be variably resistant to livestock damage. Young et al. (1941) and Tisdale (1960) found moderately heavy grazing by sheep had no effect on the natural regeneration of white pine *(Pinus monticola),* grand fir *(Abies grandis),* and Douglas-fir *(Pseudotsuga menziesii)*, but inhibited the regeneration of larch *(Larix occidentalis)* and western redcedar *(Thuja plicata).* Heavy grazing inhibited the regeneration of all conifers. McLean and Clark (1980) found negligible cattle damage to lodgepole pine *(Pinus contorta)* and Engelmann spruce *(Picea engelmannii)* where intensity and period of grazing were adequately controlled. High intensity grazing over a 3-year period caused large numbers of lodgepole pine and spruce seedlings to be killed or damaged, primarily from repeated trampling.

This study reports on the susceptibility of Douglas-fir to browsing and trampling damage in the redcedar zone of northern Idaho the first year after planting.

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Study Area

The study site was located 16 km north of Headquarters, Idaho, and is generally classified as a western redcedar/myrtle pachistima *(Pachistima myrsinites)* habitat type (Daubenmire and Daubenmire 1968). It grades into a subalpine fir *(Abies lasiocarpa)*/myrtle pachistima habitat type at the slope base. A mature stand of western redcedar was logged in 1976 and thus created a 75-ha clearcut. In 1977 the slash was dozer-piled and burned, and in April 1978 the site was planted with container-grown Douglas-fir seedlings to an 8-ft (2.4-m) spacing. The seedlings have an average height of 24 cm and an average diameter of 3.0 mm.

Although a grazing allotment encompassed the plantation, the permittee was instructed to keep his livestock away from it by using temporary fences, riders, and different salting patterns. Nonetheless, about 5 to 25 cows and calves were periodically on the plantation from June until the end of October 1978. Only minimal and largely unsuccessful attempts were made to keep the livestock off the plantation. An actual stocking rate could not be calculated; however, estimates based on the plantation size and forage abundance indicated grazing intensities to be much less than intensities under conditions of normal permitted use. The number of seedlings trampled can serve as a relative index to grazing intensity (King et al. 1978). Animals congregated at the bottom of slopes and routinely traveled over low saddles and along hilltops.

Methods

A total of 842 seedlings were monitored every 3 weeks from 15 June until 1 October, 1978, for browsing and trampling damage. The seedlings were examined from three .3-ha (.75-acre) macro-

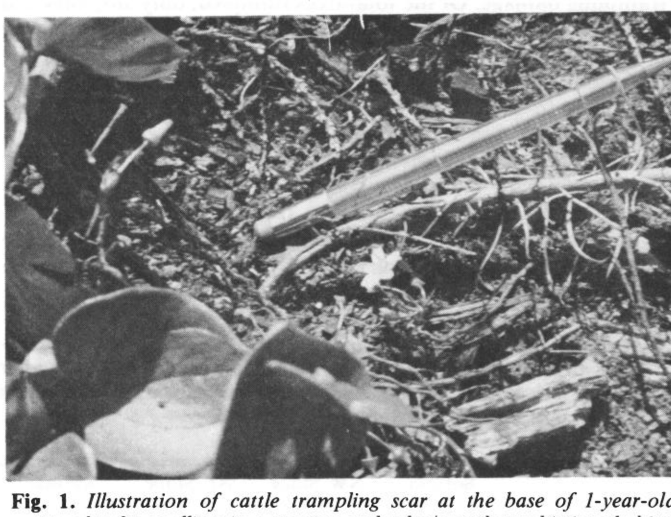

Fig. 1. *Illustration of cattle trampling scar at the base of 1-year-old Douglas-fir seedling in a western redcedar/myrtle pachistima habitat type.*

Table 1. Frequency response of Douglas-fir seedlings to animal damage in the first year of planting in a western redecar/myrtle pachistima habitat type in northern Idaho. Condition measurements were made 6 months after planting, in October 1978.

	Trampled			Browsed		No apparent animal damage	Total
	Cattle	Elk	Unknown	Deer	Gopher		
Bottomland							
Alive	1	0	7	2	0	118	128
Dead	45	3	17	0	8	60	133
Total	46	3	24	2	8	178	261
Southwest Slope							
Alive	7	1	4	2	0	192	206
Dead	22	1	11	0	5	41	80
Total	29	2	15	2	5	233	286
Northeast Slope							
Alive	9	0	11	11	0	211	242
Dead	9	0	12	2	3	32	58
Total	18	0	23	13	3	243	300

plots, selected to represent a cross section of the study area. The 3 sites were a northeast slope, a southwest slope, and a shallow draw (bottomland).

Trampling was strictly defined as any mechanical damage causing removal of the bark and exposure of the cambium (Fig. 1). The amount of bark removed was not measured, although a few scars exceeded 30% of the stem's circumference. Other forms of injury associated with trampling such as bending of the stem, soil compaction, or soil erosion and subsequent exposure of the roots were not classified as trampling because of their poorly defined nature and relatively high risk of biasing the results. Trampling was only attributed to a particular animal if a track was seen within 0.5 m of the tree seedling.

Browsing was determined by the location, angle, and sharpness of the cut. Ungulate browsing creates torn edges due to the lack of upper incisors, while browsing by rodents generally creates a clean cut (Lawrence et al. 1961). Different types of rodents can often be distinguished by the angle and location of the cut, or by the width of the gnawing marks. Early spring ungulate browsing was classified as deer or elk if it occurred prior to cattle entering the plantation. Pocket gopher browsing was generally characterized by the presence of soil mounds or soil casts with frequent removal of the root system.

Results and Discussion

A total of 160 trees or 19% were trampled during the first summer (Table 1). Cattle were responsible for at least 60% of the trampling damage. Of the total trees trampled, only 36% survived until October 1978 (Table 2). The overall rate of survival for untrampled seedlings was 77%. Trampling damage was negligible the second and third years after planting, since a much better effort was made to keep cattle out of the plantation. During this time period several trees were observed bruised by deer and elk hooves, but few had their cambium exposed to drying or infection. Douglas-fir bark by the second year after planting apparently is much firmer and less susceptible to tearing.

Few trees were browsed in the plantation (Table 1). Although no trees browsed by gophers survived, deer and elk browsing apparently had no effect on tree survival.

Table 2. Mortality probabilities of trampled Douglas-fir seedlings compared to untrampled seedlings. Measurements are for 6 months after planting in a western redcedar/myrtle pachistima habitat type of northern Idaho (sample size in parentheses).

	Bottom	SW Slope	NE Slope	Average
Trampled	.89 (73)	.52 (46)	.51 (41)	.64
Untrampled	.36 (188)	.23 (240)	.10 (259)	.23

Trees that had been trampled the first growing season were much more likely ($\alpha = .0001$) to die than untrampled trees (Table 2). The probability of a trampled seedling dying in the bottomland site was higher than on the slopes, but so was the mortality not associated with trampling. Testing the site by trampling mortality interaction (Snedecor and Cochran 1967) failed to show any significance ($\alpha = .05$).

Container-grown Douglas-fir seedlings are extremely susceptible to trampling damage the first year after planting. Unlike slash pine (Lewis 1980b), exposure of just a portion of the cambium in Douglas-fir (partial girdling) greatly increases the chances of the seedlings dying. Although a clumped livestock distribution had not been addressed in other studies (Clark and McLean 1978, Pearson et al. 1971), the uneven trampling damage common to plantations in northern Idaho further enhances the danger of grazing plantations too early. Timing of plantation grazing needs to be assessed with regards to the relative susceptibility of the difference trees species as well as the topography and habitat type.

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Diurnal Variation in Weight and Rates of Shrink of Range Cows and Calves

R.K. HEITSCHMIDT

Abstract

Cow-calf pairs were weighed on successive mornings to determine the effects of time on total weight. Early morning weights of mature Hereford/Angus crossbred cows were approximately 2.5% less than late morning weights in both the spring and summer. Weights of suckling calves were not significantly different between early and late morning. Linear regression analyses indicated drylot shrink weights of cows were primarily a function of length of time of shrink. Rate of weight loss was approximately 1% every 3 hours after an initial 3 hour loss of 3.5%. Secondary factors were status of cow (dry or wet), relative humidity (%), season (spring or summer) and initial cow weight. Shrink rates were slightly greater for wet cows than dry cows; when relative humidity was low; during spring; and for lighter weight cows. Rates of shrink of calves were primarily related to size of calf with calves weighing less than 53 kg (117 lb) gaining weight and calves weighing more than 53 kg losing weight.

Differences in liveweight of livestock are often used to evaluate the effect of various experimental treatments on livestock performance. At the Texas Experimental Ranch the magnitude of weight change over time of individual cows and the weaning weight of their calves are the principal parameters utilized to contrast the effects of stocking rate, grazing system and level of winter supplement (Heitschmidt et al. 1982). Because of the number of cattle in each treatment herd, gathering and weighing generally begins in early morning and extends into the early afternoon over a period of 3 days. Thus, weight differences between herds may reflect not only treatment effects but also the effects of the time of day the animals were gathered and weighed.

The first objective of this study was to quantify differences in cow and calf weights as a function of time of day when weighed. The second objective was to examine the rate of drylot shrink of both cows and calves as a function of length of shrink, environmental conditions, initial weight and time of day when the animals were gathered and penned. This objective was established to evaluate the feasibility of gathering herds and weighing after a predetermined period of shrink so as to standardize weights.

Methods

The study was conducted during the spring and summer of 1979 at the Texas Experimental Ranch located (99° 14'W, 33° 20'N) in Throckmorton County in the Northern Rolling Plains. Two of the 3 herds in a 4-pasture deferred rotation system (Merrill 1954) were selected for study. Each herd consisted of 24 Hereford/Angus crossbred cows of similar size and age. Ten of the 48 cows did not calve or had lost their calf prior to the study being initiated. Average date of calving for the 38 calves was mid-December. Both herds were located in pastures approximately 1.0 km from the weighing facilities.

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Experiment 1 was designed to examine the differences in cow and calf weights as a function of time of morning when the animals were gathered and weighed (Table 1). Experiment 2 was designed to quantify the rate of weight loss during the drylot shrink (Table 2). Both experiments consisted of replicated spring and summer trials run 1 week apart. Weighing of an entire herd generally required approximately 30 minutes. Although time to gather a herd within a pasture varied depending upon herd location, gathering and trailing time averaged approximately 1 hour. Ambient temperature (° C) and relative humidity (%) were recorded at time of each weighing event. All weights were recorded to the nearest 2.25 kg (5.0 lb).

Standard analysis of variance procedures were used to analyze the data from Experiment 1. The replicated 2X3 factorial designed model considered time of day, season of year, and herds as factors (Snedecor and Cochran 1967). Data from Experiment 2 were analyzed utilizing least squares stepwise linear regression procedures (Draper and Smith 1966). A series of analyses were run with percentage shrink as the dependent variable. Independent quantitative variables included individual pre-shrunk weights and time weighted averages for temperature (° C and ° F), relative humidity (%), and a temperature/relative humidity ratio (° C/%RH and ° F/%RH). Dummy variables of 1 and 0 were used for status of cow (wet or dry), season of trial (spring or summer), and initial time of day that the trial shrink was begun (a.m. or p.m.). Age of calf (days) was also included as an independent variable in the calf weight analyses. The regression procedures added independent variables if they met the $P = 0.50$ level of significance for the partial F-value. All variables included in the models and discussed in this paper were highly significant ($P<0.01$) as were the R^2 values.

Results and Discussion

Time of Weighing

The analysis of variance indicated that lactating cows with calves (wet cows) gain a significant ($P<0.01$) amount of weight during mornings. Early morning weights averaged 457 kg while late morning weights averaged 468 kg. The analyses also indicated that cows in herd A were significantly ($P<0.05$) lighter (459 kg) than cows in herd B (466 kg) and that the cows weighed significantly ($P<0.01$) more in the summer (476 kg) than in the spring (449 kg). All first order interactions were nonsignificant ($P<0.05$).

The significant weight increase during the morning was assumed to be the result of increased rumen fill in conjunction with grazing. Taylor (1954) reported that the weight of the contents of the alimentary tract of mature cattle range from 12% to 22% of the total liveweight. Thus, differences in level of fill can dramatically affect liveweights. Under range conditions, Hughes and Harker (1950) reported that 600 kg steers gained weight while grazing at a rate of 11.4 kg/hour and lost weight while resting at an average rate near 2.0 kg/hour. Thus under range conditions, grazing behavior is the major factor altering level of rumen fill at any give time. The reported effects that such factors as quantity and quality of available forage (Hughes 1976), type of grazing system (Taylor 1954), and availability of water (Whiteman et al. 1954) have on level of rumen fill are directly related to the effect these factors have on

Table 1. Calendar date, herd, time of weighing (CST), temperature (°C), and relative humidity (%) at time of weighing and average weights (kg) for Experiment 1.

Date	Herd	Time	°C	% RH	Weight		
					Wet cows	Calves	Dry cows
May 8	B	7:00	20	96	440	150	475
	A	10:45	27	58	447	144	458
May 9	A	7:45	21	80	432	143	447
	B	10:15	24	64	451	151	480
May 15	A	6:15	12	90	445	151	462
	B	10:15	24	34	464	161	492
May 16	B	6:15	11	100	456	162	492
	A	10:00	22	40	456	153	470
July 23	A	7:30	23	98	466	215	503
	B	10:30	35	30	484	230	532
July 24	B	7:30	23	85	478	228	527
	A	10:30	30	45	479	217	508
July 30	B	7:30	26	72	476	233	532
	A	10:30	32	72	484	226	515
July 31	A	7:30	22	100	461	223	501
	B	10:30	23	85	477	232	527

grazing behavior (Hughes and Harker 1950).

Results from the last trial of the study (July 30 and 31) emphasized the effect that environmental factors can have on the weight of a grazing animal if grazing behavior is altered such that level of fill is affected. July 30 was a clear, warm summer day and cow weights were very similar to those for the same time of day on July 23 and 24 (Table 1). But the weights on July 31 were well below those expected presumably because rumen fills were less than expected. Apparently the cows did not graze during the morning of July 31, a change in grazing behavior which presumably was related to the rain (Table 1). Excluding the weights from the last trial, percentage differences in wet cow weights between early and late morning ranged from a maximum of 3.4% for herd A on May 8 and 9 to a minimum of 1.3% for herd B on July 23 and 24. The average gain during mornings for all the trials was 2.5%

Although the weight gain of dry cows from early to late morning was statistically nonsignificant, trends were similar to those established for wet cows although of reduced magnitude. Averaged across all trials, weights increased during mornings 1.1% ranging from an increase of 2.8% in herd A during the last trial to a decline of -0.9% in herd B on the same date. These extremes during the last trial were likely related to the weather conditions as discussed earlier. Excluding these data, morning weight gains ranged from zero to 2.4% with an average gain of 1.0%. The reduced magnitude of morning weight flux of the dry cows in contrast to the wet cows was presumed to be related to two factors; rumen fill and milk secretion. Allen (1946) reported that weights of lactating animals fluctuate more within a day than nonlactating animals because of the relatively greater quantities of food and water that are consumed by lactating animals, as well as the loss of weight resulting from milk secretion.

Analyses of the calf weights indicated no significant ($P<0.05$) differences between early and late morning weights or between herds although calves were significantly ($P<0.01$) heavier in the summer than the spring. All first order interactions were nonsignificant ($P<0.05$). The absence of a significant treatment by season interaction indicated that treatment effects did not become significantly more pronounced as the calves grew during the spring and summer. However, gains during the morning averaged 0.6% in May, ranging from -0.6% to 1.7%, while in July gains averaged 0.9% ranging from -0.2% to 1.5%. Although statistically nonsignificant, this 0.3% average increase indicated that as the calves grew, diurnal variation in liveweights was becoming more pronounced. This would be expected since Kirton and Paterson (1971) reported that the weight of the stomach contents of 3-day-old calves was only 4% of total liveweight as opposed to the 12% to 22% reported by Taylor (1954) for mature cattle.

From these analyses it was concluded that range cows generally gain weight from early to late morning if permitted to graze but the effect that the time of day has on the weight of suckling calves is minimal.

Rate of Shrink

The stepwise linear regression selected time in drylot (x_1) as the best single variable for predicting the percent shrink of the cows (Table 3). The +0.35 coefficient indicated rate of shrink averaged approximately 1% every 3 hours after an initial 3-hour shrink of approximately 3.5%.

When percent shrink was plotted against hours in drylot, an obvious curvilinear relationship was apparent (Fig. 1). When the data were fit by least square regression procedures to the allometric function of $y = ax^b$, the R^b value increased to 0.69. This increase in the R^2 value was attributed primarily to a better fit of the data when shrinks were less than 7 hours. For example, at 3 hours predicted shrink from the equation $y = 2.43 + 0.35X_1$ was 3.48% as compared to a predicted value of 2.53% from the allometric function of $y = 0.16X_1^{0.70}$. The herd means for percent shrink from the field

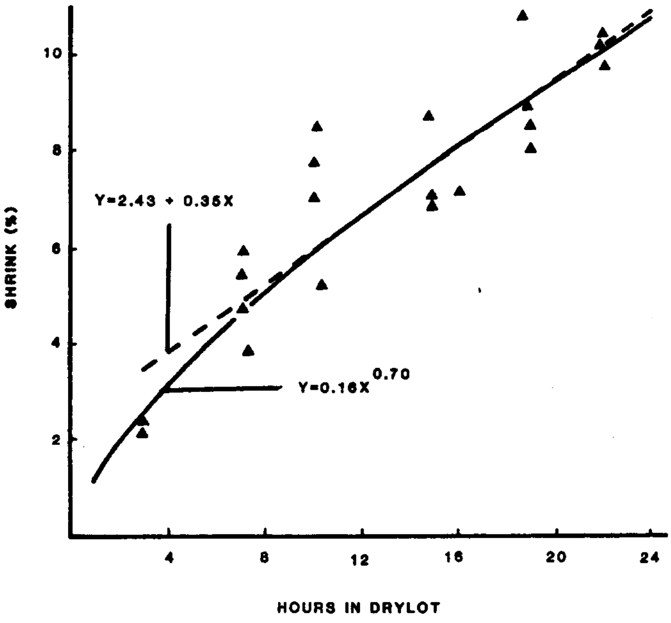

Fig. 1. *Percent loss of weight (Y) of range cows as a function of hours in drylot (X) at the Texas Experimental Ranch.*

Table 2. Calendar date, herd, time of weighing (CST), temperature (°C) and relative humidity (%) at time of weighing and average weights (kg) for Experiment 2.

Date	Herd	Time	°C	% RH	Weights		
					Wet cows	Calves	Dry cows
April 25	A	7:00 am	18	82	425	130	443
		2:00 pm	31	20	399	126	421
		5:15 pm	24	32	388	125	415
April 25	B	4:40 pm	18	82	440	137	481
April 26		7:25 am	10	64	399	135	449
		11:20 am	18	42	388	133	441
May 3	B	6:45 am	16	96	434	145	473
		1:55 pm	12	100	416	141	459
		4:45 pm	11	100	409	141	455
May 3	A	3:45 pm	11	100	441	140	458
May 4		7:45 am	7	90	409	138	428
		10:30 am	11	70	401	137	422
		2:00 pm	11	58	395	136	417
July 9		6:00 am	21	90	466	203	502
		9:00 am	32	40	455	200	494
		1:00 am	37	26	440	196	479
		4:00 pm	37	26	430	193	468
July 9	B	3:30 pm	37	26	487	217	527
July 10		6:30 am	20	96	451	210	502
		10:30 am	28	50	443	206	492
		1:30 pm	22	78	434	204	486
July 16	B	6:00 am	24	74	469	220	521
		9:00 am	29	58	457	216	511
		2:00 pm	35	28	445	213	502
		4:00 pm	37	25	434	210	492
July 16	A	3:30 pm	37	25	477	211	510
July 17		6:30 am	22	100	442	203	485
		10:30 am	22	100	437	202	479
		1:30 pm	24	72	430	200	470

data after 3 hours were 2.2% and 2.4% (Fig. 1). However, for the period from 7 to 22 hours both the linear and the allometric equations predicted percent shrink equally well. For 10 and 20 hours in drylot, predicted shrinks were 5.93% and 9.43% from the linear equation and 5.88% and 9.55% from the allometric equation. Thus, it was concluded that the linear regression adequately describe the relationship between percent shrink of the cows and time in drylot for periods of shrink between 3 and 22 hours although the allometric function described the relationship slightly better. This was a desirable conclusion since the use of linear regression procedures simplified the biological interpretation of the data. Furthermore, the level of mathematics necessary to apply the least square equations to actual field situations is considerably less when relationships are described as linear functions rather than allometric.

The rates of shrink for the cows in this study agreed rather closely with previous studies. Taylor (1954) reported drylot shrinks averaging 5.6% for 12 hours and 8.2% for 24 hours for mature steers that initially weighed 535 kg. This is in comparison to predicted shrinks for the cows in this study of 6.6% for 12 hours and 10.8% for 24 hours. In a series of trials Whiteman et al. (1954) reported overnight shrink rates ranging from 2.3% to 6.1% for growing steers that initially weighed about 415 kg. Differences in rate of shrink were related to preshrunk differences in level and type of fill. Hughes (1976) in a summarization of the findings of Whiteman et al. (1954) and other similar types of research conducted at the Grassland Research Station (1953), reported 12-hour shrinks ranging from approximately 18 kg to 40 kg for steers ranging in weight from 464 to 577 kg. Twenty-four hour shrinks ranged from 34 to 62 kg. Assuming an average pre-shrunk weight of 520 kg, the average 12-hour shrink was 5.6% and the average for 24 hours was 9.2%. Likewise, Wythes et al. (1980) reported 12- and 24-hour shrinks of 5.9% and 7.4% for steers weighing an average of 296 kg.

The second variable selected in the analyses was status (dry or wet) of cow (X_2). The +1.85 coefficient (Table 3) indicated that wet cows lost 1.85% more weight than dry cows, regardless of time of shrink. Predicted shrinks for dry cows at 12 and 24 hours were 5.2% and 9.4%. Adding the 1.85%, predicted shrinks for the wet cows were 7.0% and 11.2% for 12 and 24 hours, respectively. The increased rate of shrink for the wet cows was most likely because their preshrink level of fill was greater than that of the dry cows and they sustained a greater loss of weight because of the secretion of milk (Allen 1946).

The third variable selected was relative humidity (X_3) (Table 3). The -0.04 coefficient indicated that rate of shrink was reduced slightly as relative humidity increased. A biological explanation as to why shrink rates were reduced in conjunction with an increase in relative humidity is at best speculative since the selection of relative humidity over temperature was not expected. Paine et al. (1977) reported that increasing temperature reduced average daily gains of cattle in feedlots more than initial weight, wind speed, precipitation or relative humidity. Furthermore, it has been shown that rate of respiration of beef cattle is closely correlated with body temperature (Paine and Butchbaker 1971). Since cattle rely on respiration as the primary method of heat release (Paine 1976), one would

Table 3. Stepwise linear regression coefficients selected to predict weight loss of drylotted range cows at the Texas Experimental Ranch where y = shrink (%); X_1 = time in drylot (hours); X_2 = status of cow (0 = dry, 1 = wet); X_3 = relative humidity (%); X_4 = season of year (0 = spring, 1 = summer); and X_5 = initial weight of cow (kg). All associated R^2 values were significant at $P<0.01$ (d.f. = 503).

Regression coefficients	R^2
$y = 2.45 + 0.35X_1$	0.60
$y = 0.98 + 0.34X_1 + 1.85X_2$	0.67
$y = 3.04 + 0.38X_1 + 1.82X_2 - 0.04X^3$	0.72
$y = 5.86 + 0.39X_1 + 1.80X_2 - 0.06X_3 - 1.79X_4$	0.79
$y = 9.11 + 0.40X_1 + 1.53X_2 - 0.06X_3 - 1.45X_4 - 0.01X_5$	0.80

expect weight losses to be more closely related to temperature than relative humidity. However, because of the close relationship between relative humidity and temperature during the trials ($r = -0.85$, $P<0.01$), temperature apparently became relatively unimportant once relative humidity entered the equations.

The fourth variable selected was season of year (X_4) that the trial was run (Table 3). The -1.79 coefficient indicated that rate of shrink was less during summer than spring. However, because of differences in environmental conditions between spring and summer this coefficient only slightly modified the predicted shrink.

The final variable selected was the initial preshrunk weight of the cow (X_5). Although the -0.01 coefficient (Table 3) indicated that rate of shrink decreased slightly as initial weight increased, it is doubtful that this phenomenon was related to level of rumen fill. If it were assumed that the heavier weight cows were heavier because of greater levels of fill, then these results would be in conflict with previous findings which have shown that the greater the preshrink fill the faster the shrink (Hughes 1976). Rather, it was assumed that the -0.01 coefficient was most likely describing the interaction effect of several interdependent factors. For example, it was assumed that it reflected at least in part the slightly accelerated shrink rate that had already been established for the lighter weight wet cows as compared to the heavier weight dry cows. Also, since relative humidities were lower and temperatures were higher during the daytime shrinks than the nighttime shrinks (Table 2), shrink rates during the day would be expected to be slightly greater than those during the night. Again this would suggest that lighter cows shrink faster since the initial preshrink weights for the cows when gathered in early morning averaged approximately 13 kg less than when the cows were gathered in the afternoon for the overnight shrink.

Three independent variables did not satisfy the $P=0.50$ significance level required for inclusion. These variables were ambient air temperature, the relative humidity/temperature index and the time of day that the trial was begun. In each instance the lack of total independence from other factors already included in the model most likely diminished the significance of any of these factors.

From these analyses it was apparent that rate of shrink of the cows was primarily a function of time in drylot. This was evidenced by both the selection of time as the first independent variable and the relatively small increases in the R^2 value that occurred with the addition of each new variable.

Rate of shrink (y) of the suckling calves was primarily a function of three variables: initial weight of calf (X_1); time in drylot (X_2); and time of day (X_3) trial was begun (Table 4). The -1.60 intercept coefficient, in conjunction with the +0.03 coefficient for the preshrink weight (X_1), suggested that no shrink was predicted until calves weighed approximately 53 kg. The +0.03 coefficient suggested rate of shrink would increase slightly as initial weight of calf increased. Presumably, this slight acceleration was related to the relative increase that gut fill may have on total liveweight as an animal grows. Also, drylotting young calves does not deprive the calves of their primary food source since they probably continue to receive a near normal portion of milk.

Time in drylot (X_2) was selected as the second best variable for predicting shrink of calves (Table 4). The +0.10 coefficient suggested a slightly greater shrink occurred as time in drylot was extended. The final variable selected was time of day when the shrink was begun (X_3). The -2.45 indicated rates of shrink declined during nights in contrast to daytime shrinks. This was most likely related to the lower temperatures and higher relative humidities experienced during nights relative to days. No other variables met the $P = 0.50$ level of significance for inclusion in the model.

It was concluded from these analyses that rate of shrink of the suckling calves was minimal if the calves were left with their mother cow. This was particularly true for smaller calves. For example, after 10 hours predicted shrink for a 100 kg calf was only 0.5%. However, as the calves reached weaning weight rates of shrink began to reflect rates similar to those of more mature cattle. For example, after 10 hours predicted shrink for a 300 kg calf was 5.7%. This compares to a predicted shrink of 5.9% for a mature wet cow.

Table 4. Stepwise linear regression coefficients selected to predict weight loss of drylotted suckling calves at the Texas Experimental Ranch where y = shrink (%); X_1= initial weight of calf (kg); X_2 = time in drylot (hours); and X_3 = time of day trial was begun (0 = morning, 1 = afternoon). All associated R^2 values were significant at $P<0.01$ (d.f. = 400).

Regression coefficients	R^2
$y = -1.60 + 0.03\ X_1$	0.28
$y = -3.05 + 0.03\ X_1 + 0.10\ X_2$	0.35
$y = -4.14 + 0.03\ X_1 + 0.26\ X_2 - 2.45\ X_3$	0.41

Conclusions

These data suggest that if at all possible, cow weights obtained to contrast grazing treatment effects should be collected at a similar time of day under similar environmental conditions. These data also suggest that a period of drylot shrink prior to weighing will not standardize range cow weights unless length of shrink and environmental conditions during the shrink are similar. It is assumed, in contrast to the findings of Whiteman et al. (1954), that trailing increases rates of shrink. Thus, it is recommended that under range conditions, those cows nearest the weighing facilities be weighed first and those farthest from the facilities be weighed last.

These data indicate that the magnitude of both the diurnal weight fluctuation and the rate of drylot shrink of suckling calves is a function of size of calf in that the lighter the calf the less diurnal weight fluctuation and rate of drylot shrink. But since calves at weaning often weigh 300 kg, every precaution should be taken to obtain accurate weights especially since 10 kg differences in calf weaning weights is sufficient economic justifications for advocating certain grazing management practices. Thus, it is concluded that the same order of weighing utilized to weigh the cow herds should be followed when weighing the calves.

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Evaluation of Different Calculation Procedures for Microhistological Analysis

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Abstract

This study evaluated 3 procedures for calculating dry weight composition of forage mixtures when microhistological analysis was used. Dividing the frequency of each species by the total frequencies of all species gave a slightly more accurate representation of dry weight composition than converting frequency to relative density or using actual density. The frequency addition procedure is much quicker than either procedure involving density.

One of the basic assumptions of the microhistological technique outlined by Sparks and Malechek (1968) is that a one to one relationship exists between relative density and percent dry weight of identifiable fragments ground to a uniform size through a 1-mm screen. Sparks and Malechek (1968) determined that in 11 different mixtures the "frequency conversion" method using the Fracker and Brischle (1944) table gave the same dry weight composition estimates as the more laborious "particle count" (density) method. The mathematical rationale for converting frequency to density in microhistological studies is discussed by Johnson (1982). Sparks and Malechek reported that frequency observations from 100 microscope fields examined at 125× gave an accurate evaluation of plant fragments on microscope slides. However, they did state that exceptions may exist. Other studies conducted by Vavra and Holechek (1980), Johnson and Pearson (1981), Holechek and Gross (1982), and Holechek et al. (1982) have confirmed that the relationship reported by Sparks and Malechek (1968) is generally true with a few exceptions. The objective of this study was to evaluate the accuracy of 3 procedures for calculating the percent by weight of hand-compounded mixtures when microhistological analysis was used.

Methods

In the summer of 1980 10 known plant mixtures were compounded using species from semidesert range in southcentral New Mexico (Table 1). Species used in the diets included tobosa grass *(Hilaria mutica)*, mesa dropseed *(Sporobolus flexuosa)*, black grama *(Bouteloua eriopoda)*, blue grama *(Bouteloua gracilis)*, green sprangletop *(Leptochloa dubia)*, silver bluestem *(Bothriochloa saccharoides)*, Russian thistle *(Salsola kali)*, faint crown *(Aphanostephus ramosissimus)*, leatherleaf croton *(Croton corymbulosus)*, scarlet globemallow *(Sphaeralcea coccinea)*, fourwing saltbush *(Atriplex canescens)*, gray oak *(Quercus grisea)*, and honey mesquite *(Prosopis glandulosa)*. All plant material was dried in a forced air oven and ground through a micro-Wiley mill with a 1-mm screen. Five slides were prepared from each mixture by soaking diet material in sodium hydroxide as discussed by Holechek (1982) and mounted as discussed by Sparks and Malechek (1968). At least 20 frequency observations were recorded per slide to insure high repeatability between slides as discussed by Holechek and Vavra (1981). Twenty microscope fields were read at 125× for each slide by 3 experienced observers trained by Holechek and Gross (1982) procedures. All identifiable particle fragments in each field were recorded. Hairs and trichomes were disregarded. All unidentifiable fragments in each field were fully observed by moving the microscope slide to allow complete examination. Because our objective was to identify the calculation procedure giving the most accurate results, observers did not use correction factors to prevent over or under evaluation of certain species as recommended by Dearden et al. (1975), Vavra and Holechek (1981), and Holechek and Gross (1982).

Three procedures were used for estimating dry weight composition of each mixture. In the first procedure the number of identifiable fragments of each species in all fields was divided by the total number of identifiable fragments of all species in all fields. This procedure is equivalent to the "particle count" method of Sparks and Malechek (1968). Procedure two involved the conversion of frequency to density with the Fracker and Brischle (1944) table as discussed by Sparks and Malechek (1968). Procedure three involved dividing the frequency of each species by the total number of frequencies for all species.

The estimated percentage of each species in each mixture was compared to the actual percentage using the standard *t*-test and the 3 observers as replications. The percent similarity between estimated and actual dry weight composition was calculated with Kulcyznski's formula (Oosting 1956).

Results and Discussion

The frequency addition procedure gave slightly better overall accuracy than the actual density or frequency conversion procedures when similarity indices for the 10 mixtures were averaged (Table 1). Estimated and actual species values differed significantly ($P<.05$) in 38%, 38% and 31% of the cases for the

Table 1. Percent similarity between actual and estimated percent by weight mixture composition when actual density, frequency conversion, and frequency addition calculation procedures are used.

Mixture[1]	Actual density	Frequency conversion (Fracker and Brischle Table)	Frequency addition
1	95	95	95
2	95	95	97
3	76	80	87
4	97	94	95
5	92	90	93
6	75	82	76
7	87	90	93
8	94	97	97
9	83	70	88
10	93	94	94
$\overline{X}$	89	89	92

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Table 2. The percent by weight composition of 10 hand-compounded mixtures when 3 different methods are used for calculation.

	Total number of identifiable fragments in 100 fields	Percent frequency	Frequency converted to density (Fracker and Brischle table)	% dry weight using actual density	% dry weight using Fracker & Brischle frequency to density conversion	% dry weight using frequency	Actual % dry weight
Mixture 1							
Tobosa grass	33	28	33	19	18	18	20
Mesa dropseed	39	32	38	22	21	21	20
Russian thistle	36	31	37	21	21	21	20
Faint crown	28	26	30	16	17	17	20
Fourwing saltbush	38	34	41	22	23	23	20
Total	174	151	179	100	100	100	100
Mixture 2							
Mesa dropseed	144	74	135	80*[1]	80*	72	75
Russian thistle	35	29	34	20*	20*	28	25
Total	179	103	169	100	100	100	100
Mixture 3							
Black grama	26	22	25	14*	16*	19*	30
Leatherleaf croton	127	65	105	69*	66*	58*	45
Honey mesquite	31	26	30	17*	19*	23	25
Total	184	113	160	100	100	100	100
Mixture 4							
Green sprangletop	34	28	33	20	19	22	20
Scarlet globemallow	75	55	80	43	46*	43	40
Honey mesquite	65	45	60	37	35*	35*	40
Total	174	128	173	100	100	100	100
Mixture 5							
Tobosa grass	19	19	21	10	10	10	11.1
Blue grama	22	20	22	11	11	11	11.1
Silver bluestem	21	20	22	11	11	11	11.1
Leatherleaf croton	37	33	40	19*	20*	18*	11.1
Faint crown	16	16	17	8*	8	9*	11.1
Russian thistle	18	17	19	9	9	9	11.1
Gray oak	21	19	21	11	10	11	11.1
Fourwing saltbush	20	18	20	10	10	10	11.1
Mountain mahogany	19	19	21	11	10	11	11.1
Total	193	181	203	100	99	100	99.9
Mixture 6							
Black grama	96	80	129	55*	62*	56*	80
Scarlet globemallow	29	21	24	16*	11	14*	10
Leatherleaf croton	51	43	56	29*	27*	30*	10
Total	176	144	209	100	100	100	100
Mixture 7							
Blue grama	53	45	60	26*	28*	29*	33.3
Tobosa grass	56	47	63	28*	29*	31	33.3
Leatherleaf croton	94	61	94	46*	43*	40*	33.3
Total	203	153	217	100	100	100	99.9
Mixture 8							
Blue grama	44	39	50	24	25	25	25
Silver bluestem	41	37	46	22	23	23	25
Mesa dropseed	42	38	48	23	24	24	25
Scarlet globemallow	56	43	56	31*	28	27	25
Total	183	159	200	100	100	99	100
Mixture 9							
Green sprangletop	31	25	29	15*	12*	18*	25
Leatherleaf croton	136	86	196	67*	79*	62*	50
Fourwing saltbush	35	27	32	18*	8*	20*	25
Total	202	138	247	100	99	100	100

Table 2. Continued.

	Total number of identifiable fragments in 100 fields	Percent frequency	Frequency converted to density (Fracker and Brischle table)	% dry weight using actual density	% dry weight using Fracker & Brischle frequency to density conversion	% dry weight using frequency	Actual % dry weight
Mixture 10							
Tobosa grass	31	29	34	14	14	14	15.0
Black grass	26	26	30	12	12	12	12.5
Silver bluestem	24	23	26	11	11	11	12.5
Mesa dropseed	38	38	48	17*	20	18	20.0
Green sprangletop	11	10	10	5	4	5	5.0
Russian thistle	13	13	14	6	6	6	5.0
Faint crown	8	8	8	4	3	4	5.0
Leatherleaf croton	22	20	22	10*	9*	9*	5.0
Fourwing saltbush	34	32	38	16	16	15	15.0
Honey mesquite	12	12	13	5	5	6	5.0
Total	219	211	243	100	100	100	100.0

[1]*Observed value differs significantly ($P<.05$) from the actual value.

actual density, density conversion and frequency addition techniques, respectively (Table 2).

Most of the mixtures containing leatherleaf croton showed poor agreement between estimated and actual species values regardless of the diet calculation technique used (Table 1). This is explained by the fact that leatherleaf croton requires the use of a correction factor for accurate estimation because of excessive fragmentation.

The frequency addition procedure did not provide the most accurate evaluation of dry weight composition for all mixtures. Mixture six (Table 2) demonstrates that when an overestimated species is a minor mixture component, the density conversion procedure actually gives the most accurate results. This is because the Fracker and Brischle (1944) conversion increases the density of a species with a high frequency to a greater extent than for a species with a lower frequency. Conversely mixtures three and nine demonstrate how the Fracker and Brischle (1944) conversion can severely reduce accuracy when the overestimated species is a major mixture component. The higher accuracy of the frequency conversion procedure is explained by the fact it reduces overestimation of species with easily identifiable fragments and/or that fragment excessively during sample preparation. This source of error is magnified by the actual density procedure. The density conversion procedure either magnifies or reduces this source of error depending on whether the frequency of the overestimated species is low or high in relation to other species in the mixture.

Our results indicate that the frequency addition procedure gives equal or better accuracy than the frequency to density conversion or the actual density procedure for calculating relative percent dry weight composition. It has the additional advantage of being much quicker and more simple.

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Preference of Pygmy Rabbits (*Brachylagus idahoensis*) for Various Populations of Big Sagebrush (*Artemisia tridentata*)

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Abstract

Pygmy rabbits were used in feeding trials to rate preference of 15 populations of 2 subspecies of big sagebrush *(Artemisia tridentata* ssp. *vaseyana, Artemisia tridentata* ssp. *tridentata).* Monoterpenoid content of sagebrush was determined for each population in the feeding trials and related to food preference. The rabbits showed no significant preference for one *Artemisia* subspecies over the other; instead, selection was made at the population level. There was no significant correlation between monoterpenoid content and dietary preference of pygmy rabbits.

It has been reported by a number of researchers that wintering mule deer prefer some populations and subspecies of big sagebrush *(Artemisia tridentata)* over others (Plummer et al. 1968, Hanks et al. 1971, Scholl et al. 1977, McArthur et al. 1979, Welch and McArthur 1979, Welch et al. 1981). Hanks et al. (1971) and Sheehy (1975) reported that wintering sheep expressed similar differential preferences for populations and subspecies of big sagebrush. Determining wintering mule deer or sheep preferences for populations or subspecies of big sagebrush is an arduous and time-consuming process. Paper chromatographic and ultraviolet light tests lack the sensitivity to differentiate preference among populations in a given subspecies (Hanks et al. 1971, and Stevens and McArthur 1974). Pygmy rabbits *(Brachylagus idahoensis),* described by Green and Flinders (1980) as having an "obligate-like" relationship with big sagebrush, may be useful as a laboratory test animal in evaluating the preferences of wintering sheep and mule deer for certain sagebrush populations.

Even though big sagebrush comprises 97 to 99% of the winter diet of pygmy rabbits, nothing is known about the preference of these ànimals for certain populations or subspecies of big sagebrush (Wilde 1978, Green and Flinders 1980, White et al. 1982). This study is the first part of a two-part project aimed at determining the usefulness of pygmy rabbits in evaluating animal preference for certain big sagebrush populations. The purpose of this study was to determine if pygmy rabbits prefer some populations of big sagebrush over others. A secondary purpose was to relate the monoterpenoid content of big sagebrush populations to possible preference differences (Barbar et al. 1969, Sheehy 1975, Scholl et al. 1977, Nagy and Regelin 1977).

Methods and Materials

A laboratory colony of 15 pygmy rabbits was established at Brigham Young University for use in this study. Rabbits were trapped at the U.S. Sheep Experiment Station near Dubois, Idaho. Upon arrival at the laboratory, rabbits were dusted for fleas and placed in individual pens. Every other day, rabbits received fresh sagebrush *(Artemisia tridentata* ssp. *vaseyana* and ssp. *tridentata)* from various locations around Provo, Utah. Guinea pig food pellets containing 17.0% crude protein, 4.0% crude fat, 12.0% crude fiber, and mineral supplement were continuously available to the rabbits. Ten rabbits were selected to determine preference for various subspecies and populations of big sagebrush.

Fifteen populations of big sagebrush, which included eight populations of *A.t.* ssp. *tridentata* and 7 populations of *A.t.* ssp. *vaseyana,* were selected to test for pygmy rabbit dietary preference. Subspecies were identified by morphological and chemical criteria (Stevens and McArthur 1974, McArthur et al. 1979). Selection of the populations was based on sagebrush location and on the travel time needed to collect 2 distinct populations of each of the 2 subspecies.

The preference trial was initiated as a randomized block design consisting of 10 blocks per trial. A block consisted of a single rabbit in a 61 × 77 × 46 cm cage. Each of the rabbits had access to 4 different populations of big sagebrush at one time. Each trial consisted of 2 populations of *A.t.* ssp. *tridentata* and 2 populations of *A.t.* ssp. *vaseyana.* A test was composed of 3 trials. Vegetative samples of big sagebrush for a set of 3 trials or 1 test were collected by establishing 3 permanent 30-m transects. The nearest-neighbor method was used to select samples (Cole 1963). Samples were taken to the laboratory and frozen at 0° C. The first of 3 successive trials began the following day. There were 2 major sampling periods: one in December and one in February. Because of deep snow and heavy deer use, some of the populations used in the December sampling period were not available for the February period. This would make comparisons between the two periods unreliable.

The locations of big sagebrush populations used in various tests are given in Table 1. A trial was conducted as follows: a 50 to 70-g sample of the 4 different populations to be tested in 1 day was attached in each of the 4 corners of the rabbit pens and left for a 20-hour period. Weights were recorded before and after the sagebrush samples were placed in pens and differences in these weights, when corrected for weight loss, were recorded as the amount eaten by the rabbit. Five control samples per population were placed outside pens and weighed at the same time as test samples. This was done in order to provide a weight correction factor. In each trial, individual populations were randomized in the pens. The 3 replications within

Table 1. Locations of 15 Utah populations of big sagebrush *(Artemisia tridentata)* used to determine dietary preference of caged pygmy rabbits.

Species	Population	City and county
Artemisia tridentata vaseyana	Fairview Canyon	Fairview, Sanpete
	Hobble Creek I	Springville, Utah
	Park City	Park City, Summit
	Wallsburg	Wallsburg, Utah
	Silver City	Silver City, Juab
	Nephi Canyon	Nephi, Juab
	Hobble Creek II	Springville, Utah
	Colton	Soldier Summit, Utah
Artemisia tridentata tridentata	Utah Lake	Lehi, Utah
	Diamond Fork	Indianola, Sanpete
	West Nephi	Nephi, Juab
	Nephi Loop	Nephi, Juab
	Point of Mountain	Alpine, Utah
	St. John	St. John, Tooele
	Indianola	Indianola, Sanpete

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1 test were totaled and the average amount eaten was tabulated. It should be noted that the rabbits had continuous access to guinea pig pellets and water.

Comparison of means between preference values for population and subspecies during individual feeding trials was analyzed using group comparisons based on equal and unequal variances (Huntsberger 1967). RUMMAGE, a computer program using expected mean squares in analysis of variance, was used to determine differences among test populations (Scott et al. 1976).

Material used in determining the monoterpenoid content for each population was collected from control samples at the end of each replication and stored in the laboratory freezer at -35° C. All tissues were ground in liquid nitrogen to prevent loss of monoterpenoids. Monoterpenoids were extracted by Soxhlet extraction with absolute ether, and gas chromatographic techniques were used to separate fractions (Welch and McArthur 1981). Fractions were expressed on a percent dry matter basis.

Linear and stepwise multiple regression analysis was the basis for relating monoterpenoid content to grams of tissue consumed. Seven dependent variables were used in the multiple linear regression. These variables were the concentrations of α-thujone, camphor, α-pinene, 1,8 cineol, β-thujone, terpineol, and total monoterpenoids.

Results

Results of feeding trials for the December and February tests are given in Table 2. In the December tests, an average of 12.2 g of big sagebrush was eaten per rabbit each 20-hour testing period. During the same period, the rabbits ate an average of 15.8 g of guinea pig food pellets. Test 1 in December showed rabbits preferred big sagebrush from Diamond Fork (5.3 g) over sagebrush from Indianola (2.3 g), Fairview Canyon (2.0 g), and Hobble Creek I (1.0 g). In the December test 2, the rabbits preferred Park City (5.5 g) big sagebrush over big sagebrush from Wallsburg (2.0 g), Point of the Mountain (3.1 g), and from Utah Lake (1.3 g). December test 3 showed that rabbits preferred big sagebrush from Silver City (6.9 g) to sagebrush from West Nephi (3.8 g), St. John (2.2 g), and Nephi Canyon (1.1 g). In the December tests, the total mean consumption per rabbit of *A.t.* ssp. *tridentata* was 6.0 g and 6.2 g per population of *A.t.* ssp. *vaseyana.*

In February tests, an average of 19.5 g of big sagebrush per rabbit was eaten over each 20-hour period. During the same period, rabbits ate 14.1 g of guinea pig pellets. Test 1 in February showed rabbits preferred big sagebrush from Hobble Creek II (7.8 g) and Diamond Fork (7.7 g) over sagebrush from Indianola (2.1 g) and Colton (1.9 g). The second test in February indicated rabbits preferred Park City (7.7 g) and Wallsburg (7.0 g) samples over sagebrush from Utah Lake (2.3 g) and Point of the Mountain (1.8 g). The third test in February revealed rabbits had no significant preference for sagebrush from Nephi Loop (5.7 g), Silver City (5.4 g), St. John (4.7 g), or West Nephi (4.6 g). For the February tests, total mean consumption per rabbit of individual populations of *A.t.* ssp. *tridentata* and *A.t.* ssp. *vaseyana* was 9.6 g and 9.9 g, respectively. (Note that we had to include three populations of ssp. *tridentata* in test 3 instead of two.)

Unfortunately, December tests 1 and 3 cannot be compared with February tests 1 and 3 as some of the sagebrush populations available in December were not available in February. Unavailability was due to snow depth and to heavy usage by wintering herds of mule deer. Test 2 of the 2 sampling periods can be compared. In both periods the Park City big sagebrush was the most preferred. Big sagebrush from Utah Lake and Point of the

Table 2. The preference of pygmy rabbits *(Brachylagus idahoensis)* for subspecies and populations of big sagebrush *(Artemisia tridentata)*. Data expressed as grams consumed—two testing periods, December and February 1978-79.

Testing period	Test	Populations	$\bar{x}$	Subspecies	$\bar{x}$
December	1	Diamond Fork (t)[1]	5.3^{a}[2]	*tridentata*	7.6^{a}
		Indianola (t)	2.3^{b}	*vaseyana*	3.0^{b}
		Fairview Canyon (v)	2.0^{b}		
		Hobble Creek I (v)	1.0^{b}		
	2	Park City (v)	5.5^{a}	*vaseyana*	7.5^{a}
		Point of the Mountain (t)	3.1^{b}	*tridentata*	4.4^{b}
		Wallsburg (v)	2.0^{b}		
		Utah Lake (t)	1.3^{b}		
	3	Silver City (v)	6.9^{a}		
		West Nephi (t)	3.8^{b}	*vaseyana*	8.0^{a}
		St. John (t)	2.2^{b}	*tridentata*	6.0^{a}
		Nephi Canyon	1.1^{b}		
Period mean		All populations	3.0	*vaseyana*	6.2^{a}
				tridentata	6.0^{a}
February	1	Hobble Creek II (v)	7.8^{a}		
		Diamond Fork (t)	7.7^{a}	*tridentata*	9.8^{a}
		Indianola (t)	2.1^{b}	*vaseyana*	9.7^{a}
		Colton (v)	1.9^{b}		
	2	Park City (v)	7.7^{a}		
		Wallsburg (v)	7.0^{a}	*vaseyana*	14.7^{a}
		Utah Lake (t)	2.3^{b}	*tridentata*	4.1^{b}
		Point of the Mountain (t)	1.8^{b}		
	3[3]	Nephi Loop (t)	5.7^{a}		
		Silver City (v)	5.4^{a}	*tridentata*	5.3
		St. John (t)	4.7^{a}	*vaseyana*	5.4[3]
		West Nephi (t)	4.6^{a}		
Period mean		All populations	4.9	*vaseyana*	9.9[3]
				tridentata	9.6
Mean of both periods		All populations	4.0	*vaseyana*	8.0[3]
				tridentata	7.8

[1]t = *Artemisia tridentata;* v = *Artemisia tridentata vaseyana.*

[2]Grams of big sagebrush eaten in a 20-hour period by pygmy rabbits. Populations sharing the same letter superscript are not significantly different at the 0.05% level.

[3]A population of *A.t. tridentata* had to be substituted for a population of *A.t. vaseyana.*

Table 3. The relationship between monoterpenoids and the preference of pygmy rabbits for populations of big sagebrush. Data expressed as correlation coefficient (r) and coefficient of determination (r^2).

	Monoterpenoids							
	α-Pinene	Camphor	1,8 Cineol	α-Thujone	β-Thujone	d-Camphor	Terpineol	Total
r	-0.16	0.14	-0.14	-0.34	-0.15	0.04	-0.28	-0.26
r^2	.03	.02	.02	.12	.02	.00	.08	.07

Mountain were eaten sparsely in both periods. Consumption of the Wallsburg big sagebrush in December was also sparse, but high in the February period. We have no explanation for this difference.

The average monoterpenoid content of big sagebrush for all tests was 1.91% (data expressed on a dry matter basis-pool data from December and February). The largest fraction—pool data—was α-thujone (0.39%); camphor was the second largest (0.29%). Total monoterpenoid content for December averaged 2.17%. *A.t.* ssp. *vaseyana* (2.48%) contained a higher nonsignificant amount (p=0.05) of total monoterpenoid than did *A.t.* ssp. *tridentata* (1.87%). Camphor (0.28%) was the largest individual monoterpenoid fraction for the December period. *A.t.* ssp. *vaseyana* (0.33%) contained a greater nonsignificant (p=0.05) amount of camphor than did *A.t.* ssp. *tridentata* (0.24%).

Total monoterpenoid content for February (1.66%) was not significantly different than that for December. *A.t.* ssp. *vaseyana* (1.90%) again contained more nonsignificant total monoterpenoids than did *A.t.* ssp. *tridentata* (1.44%). In February, α-thujone was the single largest monoterpenoid fraction (0.57%). Camphor was the second largest fraction for February testing (0.31% dry matter).

Total monoterpenoid content showed no significant correlation to preference (r= -0.26), when grams of sagebrush consumed was used as the dependent variable (Table 3). However, the monoterpenoid fraction @-thujone (r= -0.34) had a statistically significant negative influence on preference. Other monoterpenoid fractions, camphor (r= -0.14), α-pinene (r= -0.16), 1,8 cineol (r= -0.14), β-thujone (r= -0.15), and terpineol (r= -0.28) had no significant correlation with preference. Stepwise multiple linear regression could account for 59% of the variation in dietary preference for sagebrush; however, this value was not statistically significant (p=0.05).

Discussion

Overall, the pygmy rabbits showed no preference for either subspecies *tridentata* or *vaseyana*. On a per test (one test, December test 1), however, ssp. *tridentata* was significantly preferred over ssp. *vaseyana;* but ssp. *vaseyana* was significantly preferred over ssp. *tridentata* in 2 tests (December test 2, February test 2). Sheehy (1975) reported that mule deer preference for taxa of big sagebrush was expressed at the subspecies level and not at the population level. Hanks et al. (1973) reported similar results. Scholl et al. (1977), Welch and McArthur (1979), and Welch et al. (1981) have shown that some accessions of ssp. *vaseyana* grown on a common site were not significantly preferred by wild, wintering mule deer over some accessions of ssp. *tridentata*. While it is a good rule of thumb that ssp. *vaseyana* is preferred by wintering mule deer over ssp. *tridentata*, it appears that some populations of ssp. *tridentata* may be preferred as well as some populations of ssp. *vaseyana* (Scholl et al. 1977, McArthur and Plummer 1978, Welch et al. 1981).

Lack of a significant relationship between preference and the monoterpenoid content of the forage has been reported for other animals (Scholl et al. 1977, Radwan and Crouch 1978). Scholl et al. (1977), studying the involvement of monoterpenoids (sagebrush) in browse preference of wintering mule deer, found that the monoterpenoid content in sagebrush accounted for only 21% of the observed variation. Radwan and Crouch (1978), studying the preference of blacktail deer for families of Douglas-fir, found that the families varied significantly in yield and composition of monoterpenoids, but the differences were not related to deer preference. These reports contrast with the findings of Nagy and Regelin (1977) and Barbar et al. (1969). Nagy and Regelin (1977), using pelleted feed of varying monoterpenoid content, found that deer selected pelleted feeds that had the lowest monoterpenoid content. Barbar et al. (1969) reported that sage grouse selected sagebrush containing the lowest concentration of monoterpenoids.

This study has demonstrated that pygmy rabbits differentially prefer certain populations of big sagebrush over others. The use of pygmy rabbits as an indicator species for dietary palatability of big sagebrush will be tested in future work with sagebrush populations preferred by mule deer, pronghorn antelope, and sage grouse.

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Effects of Livestock Grazing on Mearns Quail in Southeastern Arizona

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Abstract

Grazing by domestic livestock does not limit production of food supplies for Mearns quail *(Cyrtonyx montezumae mearnsi)* in southeastern Arizona. Nevertheless, grazing available forage in excess of 55% by weight can nearly eliminate local quail populations by removing their escape or hiding cover just prior to the nesting season. This eliminates the breeding population itself. The 46 to 50% level of utilization by weight appears to be marginal for maintaining optimum quail populations.

The Mearns quail is the northernmost of three subspecies collectively known as montezumae quail. These are endemic to the pine-oak vegetation zone of Mexico with the range of *C.m. mearnsi* subspecies extending into portions of southern Arizona, New Mexico, and west Texas (Leopold and McCabe 1957). Arizona's population is distributed from the Mexican border north to the Mogollon Rim and from the Baboquivari Mountains east to New Mexico (Fowler 1903 in Bishop 1964, Yeager 1966). Major populations are located in the southeastern corner of the state in the oak woodland and grassland described by Lowe (1964).

In 1960 the Mearns quail was legally hunted for the first time in Arizona, and since then has become a focal point for attention from preservationists and hunters alike. The limited amount of literature on the species frequently refers to the negative effect that livestock grazing has on quail densities. However, no previous investigator brought quantitative evidence to bear on the subject, and there was a lack of agreement among investigators on how grazing actually limited populations. Leopold and McCabe (1957) felt that grazing depleted the birds' food supply. Ligon (1927) felt the problem was related to cover removal. It is the intent of this paper to explain the mechanics of the relationship between livestock grazing and quail densities and to estimate the level of grazing intensity that is limiting to local quail populations.

Methods

Information on Mearns quail food production under different levels of grazing intensity was gathered over a 9-year period. Food production (gm/ha) was estimated semiannually from stem counts of preferred Mearns quail food items on 188 9.3m^2 (100 ft^2) plots. Analysis of crop contents from collected quail dictated items to be included in stem counts. Plots were distributed among 4 different adjacent cattle pastures, each of which was grazed at a different level of intensity. Mearns quail were censused (Brown 1976) annually on these pastures.

Four other small study areas were also censused for quail in June and early July to determine the presence or absence of mated pairs within represented forage production and utilization zones. Grass production estimates were made on all areas according to procedures outlined in the U.S. Forest Service Handbook for Range Environmental Analysis (1970); and 2nd estimates of forage utilization by livestock were made to the nearest 5% (Roach 1950).

Grass production estimates were placed on maps of the study areas and isometric lines were drawn at 36.6 kg/ha (200 lb/acre) increments. Estimates of forage utilization by livestock, isometrically mapped in 5% increments, were then superimposed on the forage production maps. The final isometric maps included both production and utilization zones and represented a total of 1755 ha (6.75 mi^2) for all study areas combined. Forage production estimates were not measured on 562 ha thus classified. Production estimates for this area were derived from an immediately adjacent but smaller area of similar vegetative composition and crown cover and projected to this 562 ha with minor adjustments for differences in precipitation patterns.

A map of quail home ranges was overlaid on the production-utilization map. With this approach, it was then possible to relate pair density to production-utilization categories. When a pair home range overlapped more than a single production-utilization zone, both production and utilization were estimated for that home range as a weighted average.

All areas sampled were assumed to be capable of sustaining medium to high densities of quail under normal climatic conditions. This assumption is based on the fact that these areas contained requisite tree cover, and that the general area had sustained continuous populations of Mearns quail. Only wooded areas with 20% or greater crown cover (oak and/or manzanita), and open grassland within 45.7 m of such overstory were used. Leopold and McCabe (1957) have reported "....heavy populations (of Montezumae quail) in second growth scrub...", and have stated, "....condition of the forest canopy doesn't seem to matter...". It is doubtful, however, that they intended this to mean a total absence of large overstory. General observations made during the course of the studies reported herein indicate that Mearns quail in southeastern Arizona do not inhabit open grasslands. They inhabit wooded areas and use adjacent areas of open grassland. Open areas 0 to 22.9 m from the tree line were heavily used; areas 22.9 to 45.7 m (25 to 50 yds) were used less frequently. Sightings of birds or scratchings over 45.7 m from tree lines were unusual. Therefore, all surface area recorded in Table 4 can be considered medium to high quality Mearns quail habitat in this respect. The 20% crown cover figure is a value arbitrarily derived for the purpose of this study. Relating crown cover to quail density was beyond the scope and capabilities of the study. However, there is some indication that areas with 30% or more crown cover tended to sustain higher densities of quail than those with only 20. Only 22.3 ha of the area recorded in Table 4 had between 20 and 30% crown cover.

All study areas were located within the 1400–2000 m altitudinal range in the oak woodland and grassland (Lowe 1964) of the eastern foothills of the Santa Rita Mountains, Canello Hills, and Patagonia Mountains of Santa Cruz County, Ariz. (Fig. 1). The overstory consists mainly of *Quercus arizonica* and *Q. emoryi* with varying amounts of manzanita (*Arctostaphylos* sp.) in some areas. The grass community is almost exclusively a summer-growing

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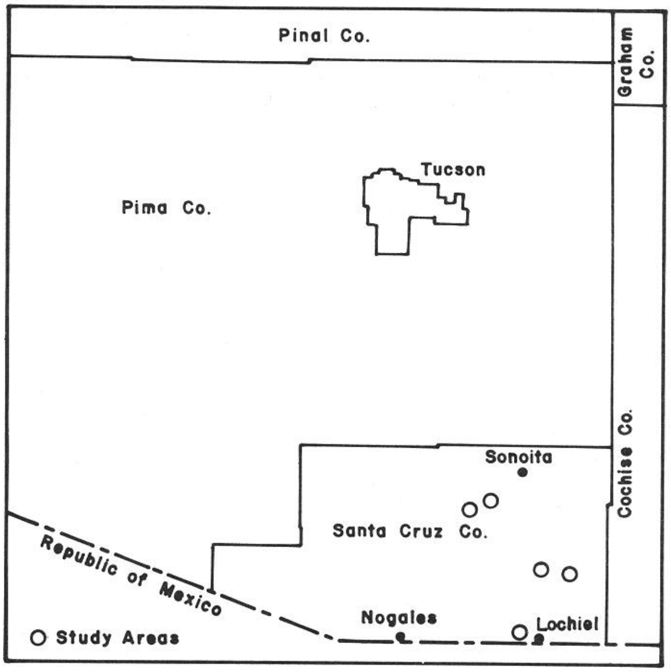

Fig. 1. *Map of Mearns quail study areas.*

perennial bunch grass type. Areas consistently grazed below the 35% level of utilization by weight are dominated by *Bouteloua curtipendula* and *Andropogon barbinodis,* with one of the study areas supporting large amounts of Texas bluestem *(Andropogon cirratus).* Steep north-facing slopes have substantial amounts of bullgrass *(Muhlenbergia emersleyi).* The most heavily grazed areas are dominated by *Bouteloua hirsuta, B. gracilis,* and *Aristida ternipes.* Topographically, the areas tend to be broken by numerous small canyons with slopes of 20 to 45°. North-facing slopes are heavily wooded with oak. Southern exposures and flatter portions tend to be open grassland (Fig. 2).

Most of the annual precipitation in this area is received during the summer monsoon season. Yearly precipitation measured at the Heady Ashburn Ranch near one of the study areas 3.2 km (2 miles) west of Lochiel, Santa Cruz County, averaged 45.2 cm for the 15-year period 1961-75. Sixty-eight percent of this fell during the June–September period, 21% during the December–March period, and the remaining 11% was received intermittently during the April–May and October–November periods.

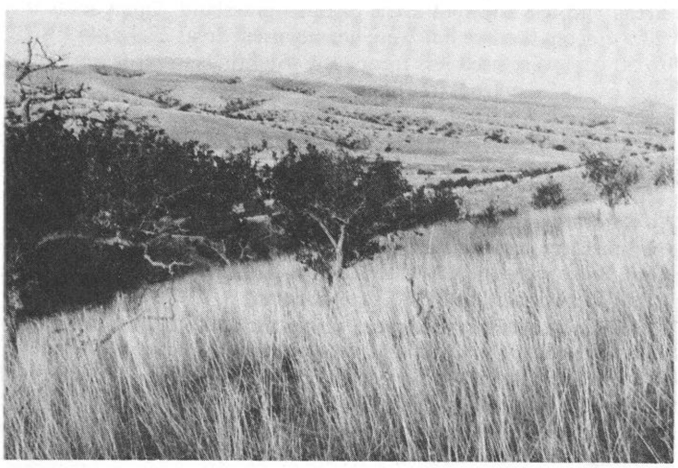

Fig. 2. *Mearns quail habitat, Santa Cruz county, Ariz.*

Results

Effects of Grazing on Mearns Quail Food Production

Plant species encountered during examination of Mearns quail crop contents are listed in Table 1. Average annual quail food production estimates (Table 2, which contains all Table 1 species combined) correlated ($r=0.905$ $p\leq .10$) with forage utilization estimates made on forage plots within those pastures. The more heavily grazed pastures were also the most productive. The severely grazed portion of the Clopton pasture (Table 2) produced nearly twice as much quail food as the moderately grazed Heady Ashburn pasture. A similar comparison can be made between the Clopton and the De La Ossa-Duquesne pasture. They are adjacent to each other and edaphically similar, yet the Clopton pasture produced the most quail food. The USDA Forest Service Range environmental Analysis Handbook (1970) classified all species in Table 1, except *Phaseolus acutifolius* and *Galactia wrightii*, as increasers or invaders on grazed pastures. In the Lochiel study, *Galactia* was the only species found solely in association with climax stands of grass and *Phaseolus acutifolius* appeared unaffected by grazing.

With the exception of *Arctostaphylos* sp., which is not a significant Mearns quail food under most conditions (Bishop and Hungerford 1965), all food items listed in Table 1 grow during the summer.

There is indeed a potential for grazing to reduce food supplies immediately through the removal of seed, but this potential seems slight. Three of the production estimates (seed production for *Cyperus rusbyi, C. mannimae,* and *Paspalum stramineum*) have been adjusted upward to compensate for amounts estimated to have been grazed during the summer growing season. However, in aggregate these adjusted figures comprise only 23.5% of the overall quail food production and only a portion of this would be grazed before the seed fell. Other items in Table 1 are either not grazed at all, or are grazed very lightly while contributing little to either the overall diet or production estimates. The underground bulbs of *Oxalis amplifolia* and *Cyperus rusbyi* combined, comprised 76.6% of the crop contents and 69.3% of the total food production. These of course would not be removed by grazing at any time of the year. Clearly, livestock grazing has not limited Mearns populations on these study pastures through reducing their food supply. In fact, the available information suggests that grazing is actually beneficial to Mearns quail in this respect.

Table 1. Mearns quail food items and food production estimates, Lochiel study area.

Species	Air-dry wt. crop analysis 1967–77 (188 crops)		Avg. annual production 1968–1976	
	Part	%	Gms/ hectare	%
Cyperus rusbyi	bulb	50.7	11,148	67.6
	seed	0.3	2,538	15.4
Cyperus mannimae	seed	unk[1]	81	.5
Oxalis amplifolia	bulb	25.9	272	1.7
Paspalum stramineum	seed	7.5	1,251	7.6
Galactia wrightii	seed	3.5	36	0.2
Phaseolus acutifolius	seed	3.1	212	1.3
Tephrosia tenella	seed	1.8	2	.01
Ipomea sp.	seed	1.2	[2]	
Arctostaphylos sp.	flower & fruit	0.8	[2]	
Euphorbia dentata	seed	0.6	10	0.1
Panicum capillare	seed	0.2	[2]	
Ambrosia psilostachya	seed	0.1	921	5.6
Phaseolus heterophyllus	seed	tr	22	.1
Vitis arizonica	seed	tr	[2]	
Miscellaneous	seed & tuber	4.3	[2]	
		100.0	16,493	100.11

[1]Seed cannot be differentiated from seed of *C. rusbyi.*
[2]*Production not measured.*

Table 2. Estimated Mearns quail food production, livestock utilization levels and fall covey densities (annual averages Lochiel study area).

Pasture	% plants grazed on plots 1968–76	Quail food produced gms/hectare 1968–76	# coveys/km² 1971–76
Heady Ashburn	50	10,900	10.3
De La Ossa (Lochiel Pasture)	70	13,400	8.1
De La Ossa (Duquesne Pasture)	73	12,500	9.6[1]
Clopton	91	21,200	0.0

[1]1973 through 1976 only.

Nevertheless, the conclusion that grazing can limit Mearns quail populations is unavoidable. Apparently, some critical threshold level of grazing was exceeded on the Clopton pasture which was the most heavily grazed and produced the most quail food, yet failed to successfully harbor any quail for the entire duration of the study (Table 2). This demonstrates that livestock grazing prevented the establishment of Mearns quail on this pasture through the removal of cover rather than by limiting the quails' food supply.

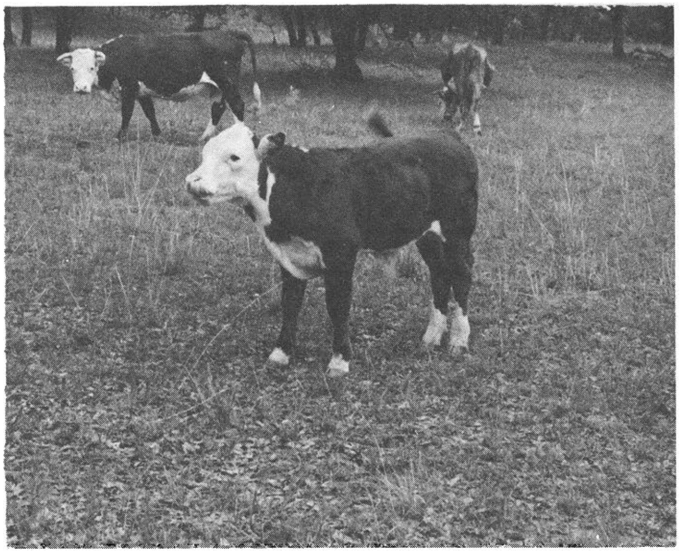

Fig. 3. *Height of new vegetation material, July 28, 1976, Lochiel Study Area. Note visibility of hooves.*

Effects of Cover Removal on Mearns Quail Populations

Excessive cover removal could affect the population in either or both of two ways. It could limit nest building itself. The nest usually has an overhead canopy of grass stems (Wallmo 1954). It could also limit the population through the removal of necessary escape cover. In the latter case, survival of individuals is directly and immediately threatened. This would occur at a time of year when the quail population is at its annual low point and therefore extremely vulnerable to any further loss of birds.

Nesting is underway before regrowth of new vegetation has

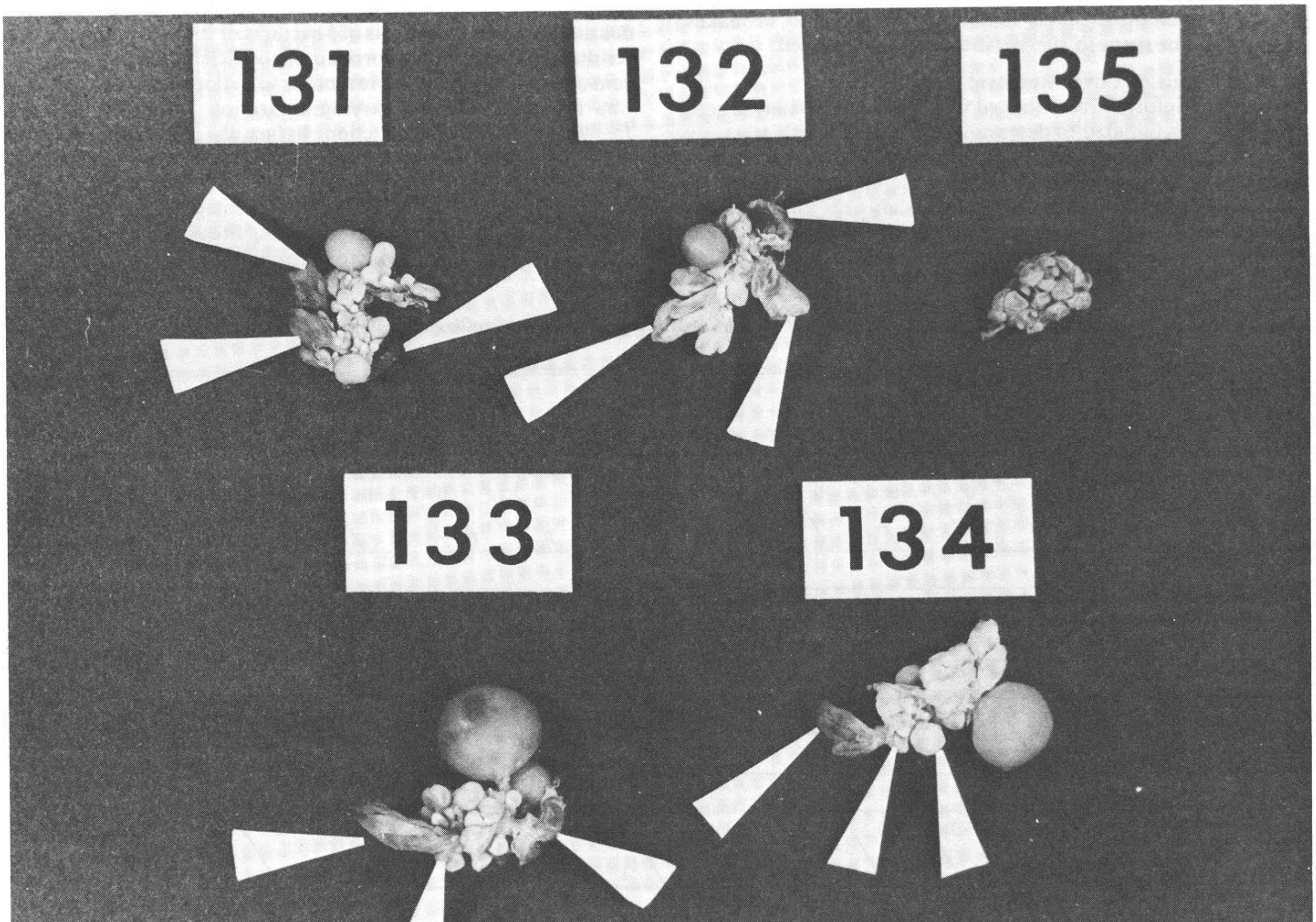

Fig. 4. *Reproductive tracts from Mearns quail shot July 21–30, 1976, Lochiel Study Area. Empty follicular envelopes are recognizable in birds No. 131-134.*

progressed to the point that it provides adequate cover for either nesting or escape (Fig. 3 and 4), and quail must rely on cover from the previous summer growing season. At the time of the Figure 3 photograph, new growth height was 152-177 mm for blue *(Bouteloua gracilis)* and sideoats grama *(B. curtipendula)*. Hairy grama *(B. hirsuta)* was 76-102 mm. Five female Mearns quail were collected in July of 1976. Numbers 131 and 132 are in the post ovulating stage (Fig. 4). Number 133 was post ovulation or ovulating and 134 was ovulating. The ovary from bird number 135 did not have identifiable empty follicular envelopes; however, the oviduct diameter, 10.0 mm at its widest point, suggests that laying had already terminated. Oviducts from pre-ovulating birds are usually about 3 mm in diameter.

The Clopton pasture not only failed to harbor any fall coveys permanently; it failed to harbor any mated pairs initially (Table 3). The adjacent more lightly grazed De La Ossa-Duquesne pasture habored both mated pairs and fall coveys during all years. The lack of mated pairs on the Clopton pasture confirms that the initial impact of cover removal is on the breeding population itself. The lack of fall coveys was due primarily to absence of an initial breeding population. During the study, two fall coveys from the De La Ossa pasture are known to have partially encroached upon the Clopton pasture for a short period of time. But, cover was removed so rapidly by grazing on the Clopton pasture that both coveys were forced back onto the De La Ossa pasture by mid-winter. This occurred at a time of the year when food supplies were high and nest material unimportant, thus indicating that lack of escape cover was the critical factor. It seems likely then that the same mechanism prevents breeding populations from becoming established. Apparently, lack of escape or hiding cover discourages mated pairs from becoming established initially and/or makes it impossible for them to survive if they are established.

Table 3. June breeding densities and forage utilization levels on two adjacent pastures—Lochiel study area.[2]

	Pastures			
	Clopton		De La Ossa (Duquesne)	
Year	Pairs/km²	% Plants grazed on forage plots (N=38)	Pairs/km²	% Plants grazed on forage plots (N=33)
1968	0	65	[1]	53
1969	0	87	[1]	60
1970	0	94	[1]	69
1971	0	96	[1]	80
1972	0	95	21.3	75
1973	0	94	17.1	77
1974	0	95	8.5	77
1975	0	95	8.5	86
1976	0	90	8.5	78

[1]Mated pairs present but in unknown number. Pasture used for induced calling 1968 and for collecting 1969-71.

[2]Average bunch grass production (1972-1975): Copton—54.0 kg/ha, De La Ossa—117.3 kg/ha.

Critical Levels of Cover Removal

Based on information obtained from the Lochiel study, a separate study was initiated to determine the level at which grass cover removal by livestock becomes critical to the establishment and survival of Mearns quail breeding populations. Data were gathered from portions of the Lochiel study area and three other small areas from 1973-1976. A fifth study area yielded data from 1970-6. The occurrence of mated pairs, classified according to weighted averages of production and utilization categories within their home ranges, was the criterion used to determine the suitability of these production and utilization zones for quail occupancy.

The correlation analysis was conducted where pair density (pr/ha) was the dependent variable and means of the production and utilization categories (Table 4) were independent variables. The pair density estimates entered into the calculations were not weighted for the number of hectares samples, although any pair density estimates from areas of 5 hectares or less were not used. The resultant multiple linear correlation coefficient was highly significant ($R = 0.685$, $P \leq .01$). Most of the variation in quail pair density was accounted for by varying utilization levels ($r = -0.653$, $P \leq .005$) rather than production. In fact, the partial correlation of quail pair density and production category was only 0.271 (n.s.) after adjusting for utilization level.

It appears from the foregoing that the degree of utilization by livestock is the overriding factor limiting Mearns quail pair density and not the inherent productivity of an area.

Table 4. Hectares sampled and numbers of mated pairs of Mearns quail by production and utilization category. (percent utilization by weight)

Kilograms forage per hectare	76–80	71–75	66–70	61–65	56–60	51–55	46–50	41–45	36–40	31–35	26–30	21–25	16–20	11–15	6–10	0–5
184–220	0/0	2.7/0	0/0	0/0	0/0	0/0	0/0	1.1/0	0/0	2.1/0	0/0	0/0	0.9/2	0/0	0/1	4.7/2
148–183	52.5/0	20.9/0	27.8/0	19.6/0	27.4/0	1.0/0	4.3/0	13.0/2	23.0/5	14.6/2	17.7/7	6.2/5	38.6/10	9.8/8	24.1/4	184.0/44
111–147	92.9/0	113.6/0	76.4/0	55.7/1	48.7/0	30.2/4	19.6/4	48.6/8	67.6/10	22.8/4	59.7/11	13.6/3	41.4/8	14.7/9	23.4/8	153.8/29
74–110	5.2/0	49.0/0	15.1/0	19.3/0	5.1/0	1.9/0	5.9/1	5.1/1	2.9/1	1.2/0	8.0/0	3.2/2	7.8/1	0/3	4.4/0	11.8/1
37– 73	10.4/0	137.1/0	24.2/0	11.1/0	7.6/0	21.2/0	8.2/1	2.8/2	3.6/0	1.1/0	0.9/2	0/0	0/0	0.9/2	3.6/0	2.1/3

Ninety-five percent of the mated pairs censused were found on areas having average utilization levels of 45% by weight or less for their entire home range, and 98% occurred at or below the 50% by weight level (Table 4). Only 2% of the pairs encountered occurred on areas whose average level of utilization was above 50% despite the fact that 49.7% of the ground sampled was grazed in excess of that point. The 46 to 50% by weight level, therefore, appears to be marginal for maintaining optimum population levels.

The Table 4 data possess one obvious peculiarity—the absence of mated pairs in areas of the 184–220 kg/ha production zone which were grazed in excess of the 20% by weight utilization level. This can probably be attributed to light sampling of ground area representing this production level. If a 111-147 kg/ha production zone will harbor mated pairs at the 46 to 50% level of utilization, then one could expect a higher production zone to do at least that well. However, during average years, the 184-220 kg/ha production zone represents a relatively small portion of the Mearns quail habitat as suggested by Table 4. Only 11.43 ha, or less than 1% of the total habitat sampled as part of this study, was represented by this production range. Seventy-eight percent of the total habitat sampled fell within the 111-184 kg/ha range, and it is this production range that deserves the primary attention. Within this production range, the 45 to 50% utilization range is marginal for Mearns quail.

Discussion and Recommendations

The following discussion is somewhat speculative, but is necessary in order to relate the foregoing results on utilization levels to Mearns quail behavior and annual population levels.

General cover conditions are of prime importance to the Mearns quail because of the escape mechanism it employs. Its initial reaction to danger is to "freeze." This characteristic is so highly developed that the quail will usually resort to it even in the middle of an asphalt road when approached by an automobile. Although effective in dense cover, the escape mechanism becomes useless, or even detrimental, once grass cover has been seriously reduced.

The perennial bunch grasses that serve as Mearns quail cover are strictly summer-growing species produced during the July–September period. Forage utilization levels from livestock grazing begin to develop in October and reach their maximum by around June 30 of the following year.

Bishop (1964) reported that Arizona Mearns quail form pair bonds as early as late February and that most quail are paired by the end of March. However, most nesting is delayed until late June or July and most broods appear in August. Information gathered under the studies reported herein is basically in agreement. Most pairing occurs during March and April, and most nesting occurs between late June and mid-August. Bishop (1964) felt that the family unit remained intact as an individual covey until time of covey break-up the following March or thereabouts, and that the covey tends to occupy the same piece of ground occupied by the mated pair. It is extremely difficult to verify adequately either of these two premises; however, observations I have made suggest both are generally correct, provided that adequate supplies of food and cover persist (Brown 1978). Following break-up of the covey, an area which during the winter months harbors a group of approximately 8 birds, harbors only 2—a mated pair. This is most likely the result of territorial behavior on the part of the male. The territory is probably a "Class A" territory, as defined by Nice (1941), containing all feeding areas as well as the nesting area. Territoriality is therefore suspected of setting density limits on the breeding population. If so, nonterritory-holding individuals are forced into areas which contain either inadequate food or cover.

The spatial factor, whether territorially maintained or not, does exist between mated pairs, and this seems to prevent population compression beyond a certain point. Under normal or stable year-to-year conditions, mated pair densities in June more closely approximate previous winter covey densities than a three-fold increase from that level (Table 5). The latter condition would, of course, exist if most members of a winter covey of 8 birds became successfully established and survived.[1] This situation existed in Big Casa Blanca Canyon during 1972 and 1974 following winters when populations were depressed. The remaining census data from other areas or during other years were obtained when population levels were relatively stable on those respective areas. During such years, surviving surplus individuals from these areas are obviously forced into less desirable areas, many of which contain either inadequate food or cover. Their immediate problem becomes one of survival, and this negates the possibility of delaying nesting until regrowth of new vegetative material provides additional cover.

Table 5. June mated pairs and winter covey densities.

Summer	Study area	No. pairs	No. coveys previous winter
1972	Big Casa Blanca Canyon	32	15
1973	Big Casa Blanca Canyon	40	36
1974	Big Casa Blanca Canyon	35	13
1975	Big Casa Blanca Canyon	34	23
1970	Little Outfit Ranch	21	20
1971	Little Outfit Ranch	19	21
1973	Dixie Mine	6	13
1974	Dixie Mine	4	5
1975	Dixie Mine	9	7
1976	Dixie Mine	9	10
1976	Lochiel (Heady Ashburn and De La Ossa Lochiel Pastures)	38	31

The fate of these nonestablished birds has not been documented. If they are forced into an area containing inadequate food, starvation becomes a factor. And undoubtedly it is a major factor, since annual food supplies are at their lowest point during this time of year (Leopold and McCabe 1957, Bishop and Hungerford 1965, Brown 1978). Quail which choose the other horn of the dilemna and move into areas which have adequate supplies of underground bulbs and tubers, but which are denuded of grass cover, probably become prime targets for raptors. Data on this source of quail loss are extremely difficult to obtain. Only 6 cases of suspected avian predation on a mated pair member were documented during the study. However, only one of these occurred within what is considered to be a zone with adequate cover; an area producing about 147 kg of forage/ha, 5 to 10% of which had been removed by livestock grazing. The other 5 cases of predation occurred in completely denuded areas. Three of these were within 18.3 m of adequate cover which the quail had left during their foraging activities. Most cases of predation have been confirmed from the evidence left. Only one case of avian predation was actually witnessed and was caused by a sharp-shinned hawk *(Accipiter striatus).* These small hawks were common in areas where the study was conducted as were the larger *Accipiter cooperii.*

The vulnerability of the population to the loss of birds during late May and June has been demonstrated artificially through the collecting of mated pairs. During the studies reported herein, a number of mated pairs were collected during spring or early summer around the periphery of the Lochiel study area over a period of 9 years. Subsequent fall censuses showed that the impact of the collecting was so severe that it could not be done in any area to be used for a population study. Areas that were used for this purpose had consistently and proportionally depressed numbers of fall coveys. If one or both members of a mated pair was collected during March or April, a single or another pair usually appeared to fill the vacancy. When a pair was collected in May or June, however, usually no replacement appeared during that nesting season. This was documented on a small scale in 1975. On an area just north of Lochiel study area that was known to contain 5 mated pairs, both members of one pair were shot during mid-April. Both members of two more pair and the female from another pair were collected during early June. A November census of the area revealed two resident coveys. Bishop (1964) reported destroying 4 pairs bonds by collecting 6 birds from a population of 9 original pairs during mid-July. This resulted in only 5, or possibly 6, coveys being present the following fall. These 2 sets of data, in conjunction with general impressions obtained during the overall collecting program in the Lochiel area, suggest that few replacement birds are available at the outset of the nesting season, and the destruction of a pair bond at that time, or just prior, usually results in the loss of a fall covey. Avian predation would, of course, have the same effect.

Regardless of whether the foregoing hypotheses are entirely correct, the evidence demonstrates that cover removal resulting from grazing can nearly exterminate a quail population if utilization levels exceed 55% by weight in an evenly distributed pattern. From the standpoint of maintaining breeding populations, excessive utilization levels which develop at one time of the year are equally detrimental to those which develop at another. If they develop in December, they will still be present in May and June, since the grass community is comprised solely of summer-growing species. Excessive utilization levels which develop by mid-winter can, of course, displace resident winter coveys; however, this is not the primary problem.

Forage production levels, and subsequent utilization levels under stable stocking rates, vary considerably from year to year as a result of varying amounts and distribution of precipitation. Recommended utilization levels must, therefore, be below the 51–55% range to compensate for dry years. While the 40 to 45% level of utilization provides a slight safety margin and should adequately compensate for minor fluctuations in forage production during most years, the 35 to 40% range is preferable as it provides some additional protection for years of extremely low forage production. As suggested by the study approach, this recommendation applies only to wooded areas and open grassland within about 46 m of this tree overstory.

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Nutrient Contents of Major Food Plants Eaten by Cattle in the South Texas Plains

C.L. GONZALEZ AND J.H. EVERITT

Abstract

From May 1975 to November 1977, whole plant samples of 6 native and 2 introduced grass species, and top pads of 1 browse (pricklypear cactus) species were collected monthly and analyzed for crude protein (CP), P, Na, K, Ca, Mg contents, and digestible energy (DE) to determine their nutritive value as range forage. Digestible energy, CP and P levels, were deficient, especially in winter and early spring for lactating cows but were near to marginal for dry cows. All other elements, except Na, were present at amounts adequate to meet all cattle requirements. Sodium levels were low, but probably would not pose a problem if free choice salt was provided. Any deficiencies may be alleviated by cattle selection of higher quality plants, such as forbs and short-lived annual grasses. Pricklypear cactus had low levels of CP, P, and Na but high levels of estimated DE (2900 K cal/kg); however, pricklypear cactus is high in soluble ash (20%) and if expressed as in vitro digestible organic matter, DE is considerably reduced. These data suggest that protein should be supplemented to lactating cows in winter and early spring while P probably should be supplemented all year.

The 7 million hectares of rangeland in the South Texas Plains make up one of the largest native range areas for beef production (cow-calf operation) in Texas (Gould 1975). Ranch enterprises are vital to the area's economy; however, it is increasingly difficult to make a profit from range operations. The key for ranchers to remain in business is to increase their production of high quality forage.

Little research has been conducted on important food plants eaten by cattle on South Texas rangelands (Davis 1952). Cattle production from rangelands depends on rainfall distribution, forage quality, stocking rates, and other management practices. Improving nutritive value of major cattle foods on native range is essential for increasing cattle production; however, range forage nutrition information is limited.

This investigation was conducted to determine the nutritive value of major range forage species eaten by cattle grazing on a red sandy loam range site. This study is part of another study, conducted by Everitt et al. (1981), that gives details on botanical composition of cattle diets and range forage availability from September 1976 to November 1977.

Materials and Methods

The study was conducted on a red sandy loam site on the Tijerina Ranch located in northwestern Hidalgo County, Texas, from May 1975 to November 1977. Details of this site were described by Everitt et al. (1981).

Six native and 2 introduced grass species, and 1 browse species eaten by cattle, were generally available on the range during the study period. These 9 species made up at least 2/3 of the cattle's diet (Everitt et al. 1981). Most of the information presented is based on these species; however, other short-lived species were temporarily available and were evaluated for their contribution to cattle's diet and nutritional requirements. Native grass species include Roemer threeawn *(Aristida roemeriana),* slender grama *(Bouteloua repens),* fringed signalgrass *(Brachiaria ciliatissima),* hooded windmillgrass *(Chloris cucullata),* red lovegrass *(Eragrostis oxylepis),* and fringeleaf paspalum *(Paspalum setaceum).* The introduced grass species were buffelgrass *(Cenchrus ciliaris)* and common bermudagrass *(Cynodon dactylon);* the browse species was pricklypear cactus *(Opuntia lindheimeri).*

Forage samples were collected monthly from pastures grazed by animals including total above ground herbage for grasses and upper pads for cactus. Composite samples from 15 or more plants of each species were washed with distilled water, dried at 65° C, ground through a 1-mm mesh screen in a plant mill, thoroughly mixed, and stored in sealed jars.

Samples were analyzed for nitrogen (N) by the Kjeldahl method (Peech et al. 1947). Percent N values were multiplied by 6.25, to convert them to percent crude protein (CP). Levels of Ca, Mg, K, and Na were determined by atomic absorption spectrometry (Boettner and Grunder 1968). Lanthanum oxide was added to Ca and Mg samples to reduce interference. Phosphorus was determined by the rapid digestion method (Bolin and Stramberg 1944). Samples were analyzed in duplicate.

In vitro dry matter digestibility (IVDMD) percentages were determined using the two-stage technique developed by Tilley and Terry (1963). Periodically, cows grazing the forage sample area were slaughtered at a nearby slaughter house to obtain rumen inocula. Rumen materials were placed in an insulated container and taken to the USDA laboratory in Weslaco, Texas, within 10 to 15 minutes after cows were slaughtered. Triplicate samples of each forage species were inoculated with rumen fluids.

To compare forage crude protein with rumen crude protein, a random sample from within each individual rumen (fluids and solids) was taken, oven dried, and processed like forage samples in duplicate for N determination. A total of 48 rumen samples from 48 cows were sampled throughout the study period. Forty-eight samples spread out over the different seasons should indicate good forage representation in cattle diets.

Dry matter digestibility values were used to predict digestible energy (DE, k cal/kg) using the regression equation developed by Rittenhouse et al. (1971) which is similar to that derived by Moir (1961). Its application to rangeland diets should indicate seasonal trends in DE. These values may be compared to cattle requirements (NRC 1976) by converting DE values to metabolizable energy (ME) using the following formula:

$$DE(M\ cal/kg) \times 0.82 = ME(M\ cal/kg).$$

This gives a DE level for lactating cows of 2.5 M cal/kg or 2500 K cal/kg and that of dry pregnant cows of 2.2 M cal/kg or 2200 K cal/kg.

Data were analyzed for variance at the 5% probability level

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Table 1. Average seasonal and concentration of P, N, and K chemical composition, digestible energy (DE), crude protein (CP), of plant species eaten by cattle on the Tijerina Ranch in south Texas.

Common name	DE[1] (Kcal/kg) S[2]	S[3]	F	W	$\bar{X}$	CP (%) S	S	F	W	$\bar{X}$	P (%) S	s	F	w	$\bar{X}$
Pricklypear cactus	3158	3166	2190	3098	2903 a[4]	5.7	6.3	5.5	5.8	5.8 b	0.10	0.12	0.08	0.08	0.09 c
Fringed signalgrass	1630	2080	1488	1590	1697 bcd	6.6	8.2	8.5	6.0	7.3 b	0.08	0.18	0.15	0.10	0.12 bc
Red lovegrass	1810	1728	1380	1910	1707 bcd	6.9	7.5	8.0	5.9	7.1 b	0.10	0.15	0.16	0.12	0.13 b
Roemer threeawn	1524	1396	1202	1218	1335 d	6.9	6.5	7.3	5.9	6.7 b	0.10	0.11	0.13	0.11	0.11 bc
Buffelgrass	1684	1942	1672	1810	1777 bcd	7.4	9.3	10.4	5.5	8.2 ab	0.13	0.19	0.23	0.23	0.19 b
Common bermudagrass	1858	1688	1492	1408	1611 cd	12.5	11.0	13.9	8.0	11.4 a	0.34	0.32	0.34	0.15	0.29 a
Hooded windmillgrass	1464	1622	1280	1432	1450 cd	7.3	8.6	8.8	6.0	7.7 b	0.11	0.16	0.18	0.10	0.13 bc
Slender grama	1512	1508	1344	1380	1436 d	7.7	7.5	7.1	4.9	6.8 b	0.13	0.13	0.16	0.09	0.12 bc
Fringeleaf paspalum	2316	2136	1830	2232	2129 b	8.7	10.4	9.6	7.2	9.0 a	0.10	0.18	0.18	0.19	0.16 bc
$\bar{X}$	1884 ab	1918 a	1542 b	1786 ab	1783	7.7 a	8.4 a	8.8 a	6.1 b	7.8	0.13 b	0.17 a	0.18 a	0.13 b	0.15

Common name	Na (%) S	S	F	W	$\bar{X}$	K (%) S	S	F	W	$\bar{X}$
Pricklypear cactus	0.02	0.01	0.01	0.01	0.01 b	3.40	3.06	3.23	3.30	3.25 a
Fringed signalgrass	0.03	0.04	0.03	0.02	0.03 b	1.22	1.75	1.70	1.01	1.42 abcd
Red lovegrass	0.03	0.04	0.05	0.04	0.04 b	0.82	0.99	1.12	0.77	0.92 cd
Romer threeawn	0.04	0.05	0.04	0.03	0.04 b	0.49	0.62	0.72	0.47	0.57 d
Buffelgrass	0.03	0.04	0.06	0.03	0.04 b	1.20	2.80	3.29	1.24	2.15 ab
Common bermudagrass	0.02	0.05	0.06	0.02	0.03 b	1.42	1.14	2.00	1.24	1.58 abcd
Hooded windmillgrass	0.06	0.09	0.11	0.06	0.08 a	1.18	1.54	1.68	0.95	1.33 bcd
Slender grama	0.02	0.02	0.03	0.02	0.02 b	0.59	0.80	0.90	0.50	0.69 d
Fringeleaf paspalum	0.08	0.11	0.09	0.06	0.08 a	1.49	2.27	2.56	1.59	1.97 abc
$\bar{X}$	0.04 b	0.06 a	0.06 a	0.04 b	0.05	1.27 b	1.74 a	1.96 a	1.21 b	1.47

[1]Digestible energy is based on IVDMD.
[2]Letters represent seasons in following order: S=spring, S=summer, F=fall, W=winter.
[3]All summer averages are for 3 years (1975, 1976, 1977); all other seasonal averages are for 2 years (1976 and 1977).
[4]Mean row or column values followed by the same letter do not differ significantly at the 5% probability level, according to Duncan's multiple range test.

(Cochran and Cox 1956). Sampling dates were used as replications. Duncan's multiple range test was used to test differences among means.

Results and Discussion

The chemical composition, CP, and DE of clipped range forages are summarized by seasons and by species in Table 1 and Figure 1.

Digestible Energy (DE) (Based on IVDMD)

Overall means of all species indicated that DE levels in summer were significantly higher than those in the fall; however, spring and winter DE levels did not differ significantly from either summer or fall. Pricklypear cactus had significantly higher DE levels than all other species during all seasons. Among the grass species, fringeleaf paspalum had higher DE levels than most other species. Generally, most grasses had higher DE levels in spring and summer and lower levels in fall and winter. Slender grama and Roemer threeawn had the lowest DE levels.

The seasonal average DE levels (1783 K cal/kg) were lower than the 2200 and 2500 K cal/kg required to meet the needs of dry and lactating cows, respectively (NRC 1976). Pricklypear cactus was the only species whose seasonal average met DE requirements for both dry and lactating cows. Similar observations have been reported for Plains pricklypear (Shoop et al. 1977). However, pricklypear cactus is high in soluble ash (20%) and if its DE level is expressed as in vitro digestible organic matter, DE is considerably lower (Everitt and Gonzalez 1981). Fringeleaf paspalum was the only grass species where DE level was sufficient to meet dry cow requirements in summer and winter. All other grasses were deficient for all seasons. Although the DE values for most grass species were low, these data agreed with those reported in other studies (Woolfolk et al. 1975, Conrad and Holt 1979, McAtee et al. 1979). Seasonally, some foods that are high in DE become available and make up for some of these deficiencies. For example, mesquite *(Prosopis glandulosa)* beans, whose DE levels average 2460 cal/kg, are available in late summer and early fall. Also, some forbs and sedges are heavily grazed by cattle during the summer and fall (Everitt et al. 1981); they may contribute substantial levels of DE.

Crude Protein (CP)

Mean CP percentages of all species were significantly lower in winter than during the other 3 seasons. Among species, common bermudagrass and fringeleaf paspalum had significantly higher mean CP levels than all other species, except buffelgrass. Generally, pricklypear had lower levels of CP throughout the year than did most grasses.

The National Research Council (NRC) (1976) recommended 9.2 and 5.9% CP for lactating and dry cows, respectively. Of the grasses studied, only common bermudagrass had a CP content that met lactating cow requirements all seasons, except, winter, when CP levels met only the requirements of dry cows. Both buffelgrass and fringeleaf paspalum met cattle requirements in summer and fall but they were deficient in winter and marginal in spring. Based on the season mean CP content for all plants analyzed, CP levels readily met requirement for dry cows, but not for lactating cows. Protein probably should be supplemented in winter and early spring.

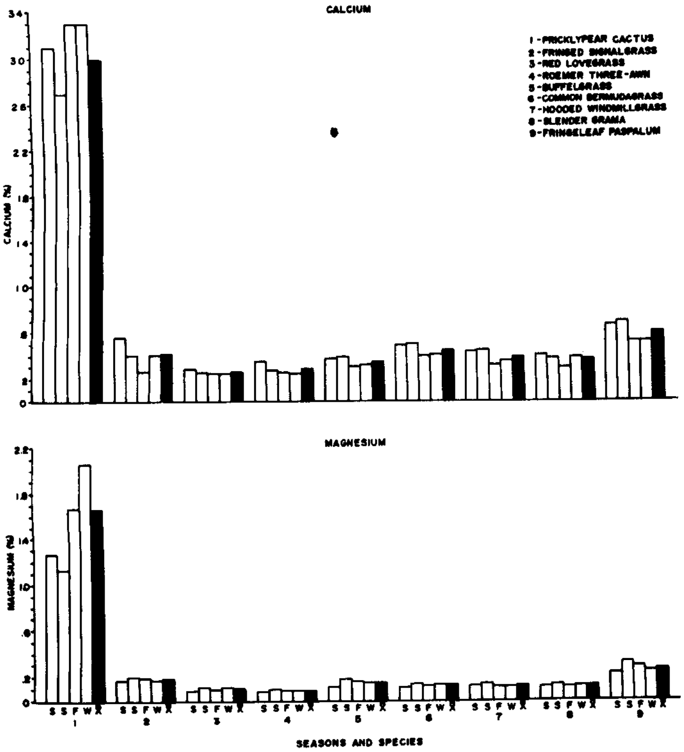

Fig. 1. *Percent calcium and magnesium contents of 8 grasses and 1 browse species used by cattle in the Tijerina Ranch in south Texas. Letters in bars are in following order: S = spring, S = summer, F = fall, W = winter and X = mean. All summer averages are for 3 years: 1975, 1976, 1977; other seasonal averages are for 2 years: 1976 and 1977.*

Phosphorus (P)

Phosphorus content of all herbage studied was generally low. Means of all species were significantly higher in summer and fall than in winter and spring. Among the species studied, pricklypear cactus had the lowest and common bermudagrass had the highest P levels. Common bermudagrass P concentration remained high during all seasons, except winter. Buffelgrass had the second highest P level among the species analyzed. Seasonal means P levels of all species for all seasons, except fall, were below the levels of 0.18 and 0.39 considered adequate for dry and lactating cows, respectively (NRC, 1976). Since P deficiencies are extremely critical, especially when Ca concentrations are high (Hill and Guss 1976), P probably should be supplemented free choice throughout the year.

Sodium (Na) and Potassium (K)

Mean levels of Na and K followed the same seasonal trend—significantly higher in summer and fall than in the spring and winter. Fringeleaf paspalum and hooded windmillgrass had significantly higher mean Na levels than all other species. Mean Na levels in forage for all species were below the 0.06% level considered adequate for beef cattle (NRC 1976). However, Na deficiencies rarely occur because it is common practice to supply salt blocks. Among the forage species analyzed, Roemer threeawn had the lowest K levels, while pricklypear cactus had the highest. The K level of all forage species were well above the (0.6 to 0.8%) minimum requirement range (NRC 1976).

Calcium (Ca) and Magnesium (Mg)

Mean Ca and Mg levels did not differ significantly among seasons; however, among species, pricklypear cactus contained significantly higher levels of both minerals. The seasonal Ca and Mg contents of each species are presented in Figure 1. All plants had Ca levels that exceeded beef cattle requirements (0.18 to 0.44%) (NRC 1976).

The required Mg level in ruminant diets depends on many factors. Although beef cattle Mg requirements are low (0.04 to 0.18%) (NRC 1976), Mg should not be deficient if K is present in excess because hypomagnesemic tetany could occur. According to Hill and Guss (1976), a forage diet with less than 20% CP and 3.0% K, should contain 0.20% Mg. All forage grasses met this requirement, thus, no tetany problem should occur. Only pricklypear cactus had excessively high Mg (1.7%) and K (3.3%) levels. However, the Mg and K levels of all grass species were within the accepted range. Most of the forage species, except pricklypear cactus, had Ca:P ratios near 2:1, which is considered ideal for ruminants according to Maynard and Loosli (1969).

Livestock Drinking Water

The chemical composition of cattle drinking water is often ignored. On this range site, well water had about 1350 ppm total soluble salts, which included 5.1, 2.9, 25.6, and 3.6% of Ca, Mg, Na, and K, respectively. Therefore, drinking water might supply elements that are deficient in range forage.

Rumen Crude Protein (CP) vs Herbage Crude Protein (CP)

Rumen CP exceeded herbage CP (by about 2%) in all seasons (Fig. 2); however, rumen CP followed the same general seasonal pattern as herbage CP. Similar observations were reported by and Shumway (1966). The main reason for higher rumen CP content in summer was probably due to selective animal grazing (Cook and Harris 1968, Nelson et al. 1970, Wallace et al. 1972). Cable and Shumway (1966) reported that in some grasses the young green material is 1.7 to 2.5 times higher in crude protein than the whole plant or older plant parts. Similar results have been reported in California (Van Dyne and Heady 1965).

Rumen CP content was high enough to meet requirements for both dry and lactating cows. However, mean herbage CP levels only met requirements of dry cows and was always deficient for lactating cows.

The fact that most samples analyzed were from whole plants might tend to underestimate the value of some nutrients, since animals are very selective and usually eat the greener and younger plant growth when available. Because the vegetation of the study area is typical of much of the South Texas Plains, these data should provide an index to the nutritional quality of forage selected by cattle in south Texas.

Summary and Recommendations

The nutritive value of major plant species of native rangeland grazed by cattle in south Texas changes seasonally. Data for 2.5 years, showed that most nutrients were more available in summer and fall than in winter and spring. Digestible energy, CP, and P levels were deficient, especially in winter and early spring, for lactating cows, but were near marginal for dry cows. All other elements were present in amounts adequate to meet all cattle

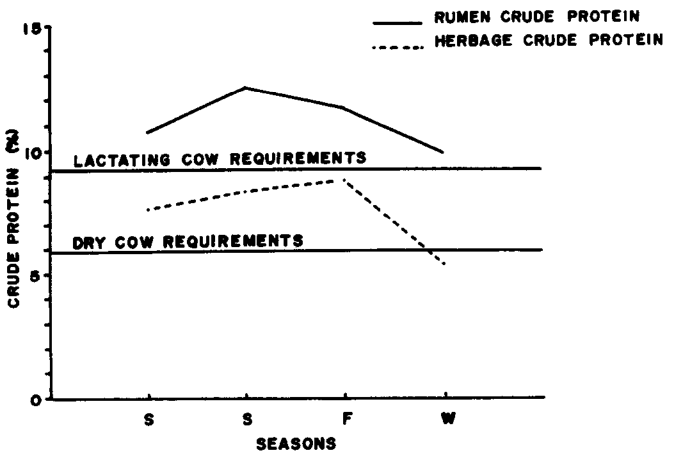

Fig. 2. *Rumen crude protein levels as compared with herbage crude protein levels during spring, summer, fall, and winter.*

requirements. Sodium levels were low in most species, but Na intake is probably adequate because salt blocks are usually provided and Na levels in cattle drinking water are high.

A comparison of herbage versus rumen CP levels showed that cattle selected a diet higher in CP than that represented by analyses of whole plant hand-clipped samples. The higher rumen CP content was probably due mostly to selective grazing or green parts of grasses, rather than to their eating the whole plant, and to the grazing of high protein forbs when they became available.

Most foods used by cattle are perennial grasses such as red lovegrass, Roemer's threeawn, and hooded windmillgrass. These species should be the focal point to determine and evaluate current cattle stocking rates. Other grasses, like fringeleaf paspalum and buffelgrass, provide a high quality food source when they are available. Although pricklypear cactus had relatively low levels of CP and P, its relatively high DE level makes it an important contributor to cattle's diets. This study suggests that protein should be supplemented to lactating cows in winter and early spring, whereas P probably should be supplemented all year.

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Forage Intake by Cattle on Forest and Grassland Ranges

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Abstract

Forage intake was determined with steers using total fecal collections on forest and grassland vegetation types on mountain range in northeastern Oregon in 1976, 1977, and 1978. Forage intake varied from 1.6 to 2.5% of body weight (BW) on dry matter basis with a mean value of 2.1%. Forage intake did not differ ($P>.05$) between the two vegetation types when data were pooled across periods and years. During the summer grazing periods cattle on the forest had higher ($P<.05$) intakes than cattle on the grassland vegetation type. This is explained by higher forb and shrub consumption, more shade and less advanced plant phenology on the forest compared to the grassland vegetation types. Fecal collections from 5 steers for 3 days were needed to estimate fecal dry matter output with 90% confidence that the estimate was within 10% of the mean.

Information on forage intake by grazing herbivores is useful to the range manager in allocating forage resources so livestock and vegetation productivity is maintained. Cordova et al. (1978) and Van Dyne et al. (1980) provide comprehensive literature reviews on forage intake by cattle and sheep on rangelands. Van Soest (1982) provides a detailed review of factors determining forage intake by ruminants. Little data are available on differences in forage intake by cattle between vegetation types, stocking rates, and years on mountain range in the northwestern United States.

Forage factors affecting cattle intake have not been evaluated in other intake studies on rangelands. Cattle on grassland ranges may have different intakes than those on forested ranges with a high component of browse. The leaves of forbs and shrubs yield their nutritional potential much more quickly than grass leaves and stems (Short et al. (1974). Rapid digestion and decomposition results in quicker rumen turnover and higher intake of shrub and forb leaves compared with grass leaves and stems. Ingalls et al. (1966) found the average rumen retention time of two grasses was 21 hours compared with 16 hours for two legumes. Arthun (1981) reported the organic matter intake by cattle was 33% higher for alfalfa hay *(Medicago sativa)* than for bermuda-grass *(Cynodon dactylon)* although the digestibility of the two forages was the same. Thornton and Minson (1973), working with sheep, found that voluntary intake was 14% higher for legumes than grasses, although digestibility was 63% for the grasses compared with 53% for the legumes. White-tailed deer intake averaged 15% higher when they were fed browse diets averaging 58% digestibility than when fed brome hay (*Bromus* sp.) averaging 72% digestibility (Robbins et al. 1975). These studies indicate that ranges supporting a high component of palatable forbs and shrubs may permit higher intakes by cattle and other ruminants than grassland ranges.

Total fecal collection has become the method of choice for determining forage intake and/or digestibility of forages consumed by grazing livestock (Cordova et al. 1978). Significant differences apparently do not exist in individual feed consumption nor body weight gains between bagged and nonbagged animals (Price et al. 1964, Phar et al. 1971). When total fecal collections are used to estimate forage intake under range conditions, they are either combined with a digestibility estimate usually obtained in vitro from samples collected by esophageally fistulated animals or with a regression equation if the fecal N method (Arnold and Dudzinski 1963) is used. One problem with this procedure is that variability in fecal excretion between individual animals is often high (Van Dyne and Meyer 1964, Minson and Milford 1967, Scales 1972).

The objectives of this study were to determine forage intake by cattle on forest and grassland ranges in northeastern Oregon during different years and to calculate the number of steers and days needed for adequate sampling of fecal output. The influence of diet nutritive quality on intake was also evaluated.

Experimental Site and Procedure

The study site was located at the Starkey Experimental Range and Forest near La Grande, Ore. Broad rolling uplands separating moderately deep canyon drainages characterize the topography of the Starkey range (Skovlin et al. 1976). Elevations range from 1,070 to 1,525 m. The average annual precipitation is approximately 59 cm, and comes as snow and rainfall in the winter and spring. In approximately 1 year out of 2, there is sufficient rainfall in the summer to result in early fall regrowth on the grassland areas.

A complete description of the vegetation on the experimental area is given by Ganskopp (1978). The primary herbage species on the grassland vegetation type are bluebunch wheatgrass *(Agropyron spicatum),* Idaho fescue *(Festuca idahoensis),* Sandberg bluegrass *(Poa sandbergii),* junegrass *(Koeleria cristata),* and common snowberry *(Symphoricarpos albus).* On the forest, the principal herbage species are Idaho fescue, elk sedge *(Carex geyeri),* Kentucky bluegrass *(Poa pratensis),* common snowberry, ninebark *(Physocarpus malvaceus)* and spiraea *(Spiraea betulifolia lucida).* Forbs and shrubs were much more important in the vegetation composition and cattle diet on the forest than on the grassland pastures (Holechek et al. 1982 a,b).

Two grassland and two forest pastures, all of equal grazing capacity, were delineated and fenced in the summer of 1975. Grazing was conducted on the pasture in 1976, 1977, and 1978. Cattle were grazed under a two-pasture-one herd rest-rotation grazing system on both vegetation types. Management under this system involved grazing one pasture all season and resting the other pasture in 1976. In 1977 grazing was conducted on the pasture rested in 1976 until mid-season when cattle were moved to the other pasture. In 1978 cattle were grazed all season on the pasture rested in 1976. Both the forest and grassland types were stocked with 18 head of yearling heifers during each year of study. In addition 8 head of experimental cattle were grazed on each vegetation type. The grazing season lasted 120 days during the 3 years of study. Cattle were placed on the pastures on June 20 and removed on October 10. The grazing season was divided into 4 periods which included June 20 to July 18 (late spring), July 19 to August 15 (early summer), August 16 to September 12 (late summer) and September 13 to October 10 (fall).

During the 3 years of study, diet samples were collected on 2 days every other week with 4 esophageally fistulated cows on each pasture. In vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD) were determined using the technique of Tilley and Terry (1963).

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Four steers fitted with fecal collection bags were used on each pasture to determine total fecal output. Total fecal collections were made from all 4 steers on each pasture on the same day every other week. This resulted in 8 estimates of intake for each vegetation type for each period of study (4 steers × 2 days). Dry matter intake and organic matter intake were calculated from total 24-hour fecal output by using the equations of Van Dyne (1968):

$$\text{Dry matter intake (DMI)} = \frac{(100) \times (\text{total fecal dry matter output})}{100 - \%\ \text{IVDMD}}$$

$$\text{Organic matter intake} = \frac{(100) \times (\text{total fecal organic matter output})}{100 - \%\ \text{IVOMD}}$$

Intake was expressed as a percentage of body weight (BW) as discussed by Cordova et al. (1978). Data on livestock performance and diet quality on the forest and grassland pastures are discussed in Holechek et al. (1981). Botanical composition data for the pastures and cattle diets on the pastures are given in Holechek et al. (1982,ab).

Correlation analysis was used to determine the relationship between intake and diet quality characteristics associated with esophageal fistula samples. These characteristics included diet crude protein %, neutral detergent fiber (total cell wall) %, acid detergent fiber %, permanganate lignin % and in vitro digestibility %. Crude protein was determined by standard AOAC (1980) procedures. Neutral detergent fiber was determined by the Van Soest (1963) procedure. Acid detergent fiber and permanganate lignin were determined by the procedure by Van Soest and Wine (1968). Intake was also related to the percent by weight of each forage class in the diet. All correlations involved a sample size of 22 for each vegetation type and were conducted using procedures of Steel and Torrie (1960). Data converted to an organic matter basis were used for all intake and diet quality correlations.

Statistical comparisons were made between the forest and grassland pasture within each period and year. A completely randomized design with a one-way classification model and a standard *F*-test were used for all comparisons (Steel and Torrie 1960). Variation associated with steers was used to estimate experimental error while variation associated with days was used to estimate sampling error (Steel and Torrie 1960). Adequacy of sample size for estimating fecal output was evaluated using the formula of Stein (1945):

$$n = \frac{(t^2)(s^2)}{d^2}$$

In this formula n is the computed sample size, t is the tabulated value for the desired confidence level and the degree of freedom of the initial sample, d is the half-width of the desired confidence interval and s^2 is the variance of initial sample. Sums of squares associated with steers and days for each vegetation type/period/year combination were partitioned using a completely randomized analysis of variance. Steer and day variances were then calculated by the formula of Steel and Torrie (1960):

$$S^2 = \frac{s_w^2}{nm} + \frac{s_a^2}{n}$$

In this formula S^2 represents the minimum variance, n represents the number of steers (4), m represents the number of days (2), s_w^2 is the sum of squares for days and s_a^2 is the sum of squares for steers. This procedure made it possible to determine the optimal number of steers and days needed for determinations of fecal output for each vegetation type.

Results and Discussion

Relative intake values (Table 1) between pastures, periods and years showed the same trends regardless of whether intake was expressed as a percentage of body weight on a dry matter basis (BWDM) or an organic matter basis (BWOM). Therefore our discussion will concern BWDM because it is more interpretable to managers.

Forage intake varied from 1.6 to 2.5% BWDM with the lowest values occurring in the late summer on the forest and highest values in the fall on the grassland. Forage intake on the forest and grassland pastures did not differ ($P>.05$) when data were pooled across years and periods. Cattle never consumed over 2.6% BWDM during any period on any pasture and average intake level was 2.1% BWDM. These intake values fall within previously reported levels. Cordova et al. (1978) and Van Dyne et al. (1980) reported that in most studies concerning cattle on ranges in the western United States intake was between 1 and 3% of BWDM. Some values reported in their reviews were 0.9 to 2.2% in Nevada (Connor et al. 1963); 1.4 to 2.6% in Nebraska (Rittenhouse et al. 1970); 1.0 to 2.4% in Colorado (Scales 1972); 0.6 to 3.6% in Oregon (Handl and Rittenhouse 1972, Kartchner 1977, Kartchner et al. 1979); and 1.7 to 2.8% in Wyoming (Jefferies and Rice 1969). On mountain range in Colorao, Streeter et al. (1974) reported average intake values of 3.1, 3.2 and 2.8% BWDM for Brown Swiss, Charolais × Angus and Hereford cows, respectively, for a grazing season that extended from June through October. In this study chromic oxide was used to estimate fecal output and the authors felt their values slightly overestimated actual intake. Cordova (1977) reported a mean intake value of 2.0% BWOM over all seasons for steers at the Fort Stanton Experimental Ranch in southcentral New Mexico. On the same range Rosiere et al. (1980) found that heifers consumed from 1.4 to 2.1% BWOM while the intake for cows ranged from 1.7 to 2.5% BWOM. Their data show that different classes of cattle do not have similar intakes even when data are corrected to body weight. Van Dyne et al. (1980) reviewed 31 studies that reported forage intake values for cattle on

Table 1. Forage intake on a dry and a organic matter basis as a percentage of body weight on the forest (F) and grassland (G) in 1976, 1977, and 1978.

	F	G	F	G	F	G	$\bar{X}$
	Dry matter basis						
Sampling period	1976		1977		1978		
Late spring	—	—	2.43	2.46	2.14[a]	2.38[a]	2.35
Early summer	2.17[a]	1.87[b]	2.15	2.12	2.05[a]	1.98[b]	2.06
Late summer	2.12[a]	2.00[b]	2.16[a]	1.97[b]	1.55	1.56	1.89
Fall	1.91[a]	2.02[b]	2.25[a]	2.54[b]	2.46[a]	2.01[b]	2.20
$\bar{X}$	2.07	1.96	2.25	2.27	2.05[a]	1.98[b]	2.10
	Organic matter basis						
Late spring	—	—	2.36	2.39	2.05[a]	2.28[b]	2.27
Early summer	2.10[a]	1.73[b]	2.06	2.04	1.97	1.94	1.97
Late summer	2.08	1.92[b]	2.05[a]	1.87[b]	1.50	1.49	1.82
Fall	1.77[a]	1.89[b]	2.16[a]	2.39[b]	2.39[a]	1.95[b]	2.09
$\bar{X}$	1.98	1.85	2.16	2.17	1.98[a]	1.92[b]	2.04

[1]Means within rows and years with different superscripts differ significantly ($P<.05$)

several different ranges using a variety of methods. They found that cattle consumed 1.8% BWDM when mean values for all these studies were averaged. During the spring and summer intake values averaged 2.1% BWDM while fall and winter values averaged 1.5% BWDM.

The summers of 1977 and 1978 were hot and cattle spent much of their time in shaded areas resting. However, the weather cooled in the fall and cattle were observed to spend more time grazing. Other researchers have reported heat stress reduced forage intake (Vohnout and Bateman 1972, Gengler et al. 1970, McDowell et al. 1976). The cooler microclimate created by the tree overstory may have contributed to increased forage intake on the forest.

Intake in the fall appeared to be dependent on fall rains and the observed subsequent forage regrowth. In 1976 and 1977 fall rains stimulated regrowth of grass on the grassland. Interception of moisture by the tree canopy may have affected the forest understory as no herbaceous regrowth was noted. Intake in 1976 and 1977 was higher ($P<.05$) on the grassland. In 1978, little precipitation occurred during the fall and cattle consumed significantly more forage on the forest.

Forage intake was higher on the forest than on the grassland in the summer during all 3 years of study. Forage species on the forest appeared to be less advanced in phenological development than on the grassland. Minson (1972) reported a substantial decline in forage intake with plant phenological advance when 6 tropical grasses were fed to sheep. During the summer cattle diets on the forest averaged 71% forbs and shrubs over the 3-year period compared to 32% on the grassland (Holechek et al. 1982a,b). Forbs and shrubs have faster digestion and passage rates in the ruminant digestive tract than grasses on basis of research by Ingalls et al. (1966) Short et al. (1974), Mertens (1973), and Milchunas et al. (1978). This could also explain the higher intake on the forest compared to the grassland during the summer periods.

The movement at mid-season of cattle on the forest in 1977 to the ungrazed pasture did not result in a significant change in forage intake. However, on the grassland, intake during the next period declined ($P<.05$) after movement indicating that intake was limited on both vegetation types by forage quality rather than availability.

Diet total cell wall % (neutral detergent fiber) was more closely associated with forage intake than other diet quality characteristics (Table 2). Our research is consistent with that of Mertens (1973) and Osbourne et al. (1974), who found cell wall % was highly associated with intake of a wide range of forages fed to sheep. Van Soest and Mertens (1977) found voluntary intake of 187 forages was more highly correlated with cell wall % than percentages of in vivo digestibility, in vitro digestibility, lignin, acid detergent fiber, crude protein, cellulose or hemicellulose. Forages with a low cell wall content typically have rapid rates of rumen fermentation (Smith et al. 1972, Short et al. 1974) and faster passage rates (Ingalls et al. 1966, Mertens 1973) than those with high cell wall content. Leaves of forbs and shrubs typically have lower cell wall contents than grass leaves and stems at comparable stages of maturity (Short et al. 1974 Huston et al. 1981).

Forages with high lignin contents (primarily forbs and shrubs) tend to have low cell wall contents and higher intakes than those of low lignin contents (primarily grasses) (Van Soest 1965, 1966). Within forage classes lignin is well related to intake but little relationship exists between intake and lignin when forage classes are mixed on the basis of studies by Osbourne et al. (1974), Van Soest (1965) and Mertens (1973).

Digestibility in our study was not highly related to intake. Part of this may be explained by environmental factors such as heat stress during the summer of 1978 that could have suppressed intake without influencing diet quality. Another important factor is that intake is more a function of passage rate than total digestibility (Mertens and Ely, 1982). Studies by Ingalls et al. (1966), Mertens (1973), Thornton and Minson (1973), and Milchunas et al. (1978) show forbs and shrub leaves, which are typically more lignified and have lower digestibilities than grass leaves and stems, have higher intakes due to more rapid decomposition and quicker passage through the ruminant digestive tract. The higher lignin content of forb and shrub leaves and stems compared to grass leaves and stems may increase passage rate by making these parts more brittle and causing finer fragmentation (Milchunas et al. 1978). Finer particles pass more quickly out of the reticulo-rumen compared to larger ones (Van Soest 1966, Mertens 1973, Milchunas et al. 1978). There is also evidence that the short, broad and cubicle shape of the forb and shrub fragments permits quicker passage out of the reticulo-rumen than the long, thin and fiber-like particles of the grasses (Troelson and Campling, 1968, Mertens 1973). We believe the fact cattle diets in our study were comprised of mixed forage classes largely explains the low association between intake and cattle diet in vitro digestibility.

Diet crude protein level in our study was not highly associated with forage intake. Milford and Minson (1965) found intake by sheep of forages about 7% crude protein was not well related to crude protein content. However, their data show intake declines precipitously in forages below this level. Apparently diet crude protein concentrations below 7% do not meet the needs of the rumen bacteria. Crude protein concentrations in our study never fell below 8% on either vegetation type (Holechek et al. 1981).

Table 2. Correlation coefficients between intake and diet quality characteristics on the forest and grassland.

	CP	NDF	ADF	LIG	IVOMD
Forest[1]	+.49*	−.71*	−.34	−.01	+.31
Grassland[1]	+.63*	−.67*	−.51*	−.21	+.55*
Forest and grassland[2]	+.56*	−.69*	−.42*	−.10	+.43*

[1]n=22.
[2]n=44.
*=Significant at $P<.05$.
CP=Diet crude protein %.
NDF=Diet neutral detergent fiber (total cell wall constituents) %.
ADF=Diet acid detergent fiber %.
Lig=Diet permanganate lignin %.

Table 3. Correlation coefficients between intake and forage class % in cattle diets from the forest and grassland.

	% Grass	% Forbs	% Shrubs	% Forbs and shrubs
Forest[1]	−.11	+.15	+.24	+.11
Grassland[1]	−.21	+.25	+.02	+.21
Forest and grassland[2]	−.16	+.20	+.11	+.16

[1]n=22.
[2]n=44.

Table 4. The number of steers and days required to determine fecal dry matter output on the forest and grassland pastures in 1976, 1977, and 1978 with 90% confidence the estimate is within 10% of the mean.

	Forest				Grassland			
Sampling period	1976	1977	1978	$\bar{X}$	1976	1977	1978	$\bar{X}$
	Number of Animals							
Last spring	—	9	4	6	—	6	4	5
Early summer	5	5	3	4	5	6	3	5
Late summer	5	5	6	5	4	7	6	6
Fall	4	5	8	6	2	5	3	3
$\bar{X}$	5	5	5	5	4	6	5	5
	Number of Days							
Last spring	—	1	2	2	—	2	3	2
Early summer	2	4	6	3	3	3	4	3
Late summer	3	3	2	3	4	3	2	3
Fall	3	2	2	2	6	3	5	5
$\bar{X}$	3	3	2	3	4	3	3	3

None of the correlations between intake and forage class were significant ($P<.05$) (Table 3). However there was a tendency for intake to be positively associated with forb and shrub consumption and negatively associated with grass consumption.

Sample size (steers × days) needed to determine fecal dry matter output at the 90% confidence level to be within ± 10% of the population mean are given in Table 4. These data indicate that 5 steers and 3 days of collection are needed to adequately sample each period.

Van Dyne and Meyer (1964) reported that 2 steers for 2 days would estimate forage intake in drylot within 10% of the mean and 95% confidence. Under grazing conditions these investigators found 4 steers were needed to estimate fecal output with the same precision level based on an average fecal output over 9 days. Van Dyne (1968) concluded about 5 steers were needed per treatment to estimate fecal output within 10% of the mean with 95% confidence. Scales (1972) considered 6 steers necessary to estimate fecal excretion within 15% of the mean with 95% confidence.

It is important to recognize that days should represent subsamples of the fecal output values of the individual steers when data are analyzed statistically. Therefore, samples should be composited across days for an estimate of experimental error. The variance associated with days represents sampling error and should not be used for testing treatment effects. Steel and Torrie (1960) provide a complete discussion of procedures for variance partitioning when the experiment involves subsamples.

Conclusions

Daily forage intake by cattle averaged 2.1% BW on a dry matter basis during typical northestern Oregon grazing seasons. Recent studies show that 2% BW provides a very good estimate of daily forage dry matter intake for cattle on most ranges when estimates are averaged across seasons. Our data were collected with steers and may not apply to other classes of cattle. Ranges supporting a high component of palatable forbs and shrubs should improve intake by cattle over ranges supporting primarily grasses, particularly during periods of forage dormancy or drought. There was no difference in intake between the forest and grassland vegetation types when data were averaged across periods and years. However cattle on the forest had higher intakes than cattle on the grassland during the summer periods. In these periods forb and shrub consumption was considerably higher on the forest than on the grassland. More shade and less advanced plant phenology also explain the higher intake of cattle on the forest compared to grassland vegetation type during the summer periods.

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Relationships between Performance, Intake, Diet Nutritive Quality and Fecal Nutritive Quality of Cattle on Mountain Range

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Abstract

Correlations were developed between average daily gain (ADG), forage organic matter intake (INT), fistula sample in vitro organic matter digestibility (DID), fistula sample nitrogen (DN), fecal sample in vitro digestibility (FID), and fecal sample nitrogen (FN) of cattle on forest and grassland range in northeastern Oregon. FN and FID were more closely associated with ADG and INT than DN or DID. Linear regression equations were developed between fistula and fecal samples for both N ($r^2 = .83$) and ID ($r^2 = .71$). The inclusion of FN as an independent variable with FID improved the equation for predicting fistula sample ID ($R^2 = .83$). Forage intake could not be well predicted from either FN or FID in either simple or multiple regression equations. The closer relationship between fecal sample nutritive quality and ADG compared to fistula sample nutritive quality and ADG is attributed to greater sampling precision for fecal nutritive quality. Fecal N and ID appear to be closely associate with DN and DID when grasses comprise most of the ruminant diet but this relationship may not hold when the diet is dominated by forbs and shrubs. Nutritive evaluation of feces shows potential for monitoring trends in ruminant diet quality and performance but much more research is needed before these procedures can be applied.

Trends in ruminant fecal nutritive quality are associated to varying degrees with trends in diet quality (Raymond 1948, Fels et al. 1959, Jarrige 1962, Arman et al. 1975, Hinnant 1979, Holloway et al. 1981) and animal performance (Erasmus et al. 1978, Gates and Hudson 1981). Three studies have shown a close relationship between percentage nitrogen in the diet and percentage nitrogen in the feces of ruminant animals (Raymond 1948, Fels et al. 1959, Hinnant 1979). A recent study indicates diet and fecal in vitro digestibility are associated (Holloway et al. 1981). Erasmus et al. (1978), in South Africa, found that trends in wild ungulate body condition were closely associated with trends in fecal nutritive quality. Gates and Hudson (1981) accounted for 85% of the variation in daily gains of elk with fecal N concentration. Based on these studies it might be possible to monitor changes in ruminant condition and diet using fecal analysis. The study reported, herein, examined the relationships between cattle performance, intake, diet nutritive quality, and fecal nutritive quality on mountain range in northeastern Oregon during 3 grazing seasons. In vitro organic matter digestibility and nitrogen were the nutritive characteristics receiving evaluation.

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Methods

The study site was located on the Starkey Experimental Range and Forest 48 km southwest of La Grande, Oregon. The range is described by Skovlin et al. (1976). A complete description of the vegetation on the study area is given by Ganskopp (1978). Two grassland and two forest pastures were used. Data on cattle diet botanical composition have been reported by Holechek et al. (1982 b,c).

Grazing was conducted on 2 forest and 2 grassland pastures of equal grazing capacity in 1976, 1977, and 1978. Grazing management involved the grazing of 1 pasture on each vegetation type all season in 1976. In 1977, cattle were grazed on the pasture rested in 1976 until midseason, when they were moved to the other pasture. In 1978, cattle were grazed all season on the pasture rested in 1976. The grazing season lasted 120 days during each year of study. Cattle were placed on the pastures on June 20 and removed on October 10. Cattle performance on the pastures was evaluated in the late spring (June 20 to July 18), early summer (July 19 to August 15), late summer (August 16 to September 12), and fall (September 13 to October 10) in all 3 years of study with 18 head of pregnant yearling heifers weighed without shrink at the onset of grazing and the end of each period.

Diet samples from each pasture were collected with 4 cows equipped with esophageal fistulas. These animals were included as part of the stocking rate and grazed continuously on each pasture throughout the grazing season. Diet samples from each cow were collected twice every other week on each pasture. Collections on the forest and grassland were always made during the same week. Data on nutritive quality of these samples were reported by Holechek et al. (1981).

Four steers in each pasture were used for fecal collections, so forage intake could be estimated. Forage intake data are reported by Holechek and Vavra (1982). One 24-hour collection was made with each steer on each pasture every other week on the same week that fistula samples were collected. Fistula samples were collected at the beginning of the week and fecal samples were collected near the end of the week. The period between ingestion and complete excretion is about 8 to 10 days for cattle fed medium quality roughages (Balch 1950). The highest rates of excretion occur 2 to 4 days after ingestion (Balch 1950). Because fistula samples were collected 3 to 4 days before fecal samples, we believe that fistula samples were representative of fecal samples. Each fecal collection was subsampled for laboratory analysis. Immediately after collection both esophageal and fecal samples were frozen. They were later dried in a forced air oven at 40° C for 7 days. After drying all samples were ground through a 1-mm screen. In vitro organic matter digestibility (ID) was determined for all samples at New Mexico State University by the technique of Tilley and Terry (1963). Nitrogen (N) was determined by Kjeldahl procedure using AOAC (1975) methods. All data were converted to an organic matter basis. Forage organic matter intake was determined from total 24-hour fecal organic matter output by using the equation of Van Dyne (1969):

$$\text{Organic matter intake} = \frac{100 \times (\text{Total fecal organic matter output})}{100 - \%\text{ in vitro organic matter digestibility}}$$

Organic matter intake was expressed as a percentage of body weight as discussed by Cordova et al. (1978).

Regression and correlation analyses were used to determine the relationships between performance, intake, diet nutritive quality and fecal nutritive quality. Ranges of values of the different parameters used in regressions are shown in Table 1. Data on diet nutritive quality and fecal nutritive quality were pooled across animals and collections within each period and vegetation type when average daily gain and intake were used as dependent variables. Livestock performance and intake data for the late spring of 1976 were not used in regression models because of a water quality problem on both vegetation types which was corrected in early July. Fistula sample values were pooled across animals (4) and collections (2) within each sampling week when diet ID and diet N were used as dependent variables. Fecal sample N and ID values were pooled across animals for use as independent variables in these regressions. Regression equations were developed for the forest and grassland pastures both individually and together using

Table 1. Range of values of average daily gain, intake, diet nutritive characteristics and fecal nutritive characteristics.

	Range of values
Grassland	
Average daily gain	-.37 - +0.80 kg
Intake	1.49 - 2.31%[3]
Diet nitrogen percentage[2]	1.04 - 2.36%
Diet in vitro digestibility[2]	39.6 - 65.1%
Fecal nitrogen percentage[3]	1.53 - 3.21%
Fecal in vitro digestibility[2]	11.20 - 27.50%
Forest	
Average daily gain	-.40 - +1.10 kg
Intake	1.50 - 2.39% BW[3]
Diet nitrogen percentage[2]	1.21 - 2.36%
Diet in vitro digestibility[2]	38.90 - 66.90%
Fecal nitrogen percentage[2]	1.58 - 3.41%
Fecal in vitro digestibility[2]	9.20 - 26.30%

[1]Forage intake is expressed as organic matter as a percentage of body weight.
[2]All nutritive quality data are on an organic matter basis.
[3]BW = Body Weight

Table 2. Matrix of correlation between livestock performance, forage intake, diet nutritive characteristics and fecal nutritive characteristics for forest and grassland vegetation types combined.

	ADG[1]	INT[2]	DN[2]	FN[2]	DID[2]
INT	+.51*				
DN	+.53*	+.56*			
FN	+.69**	+.66**	+.91**		
DID	+.60**	+.43*	+.67**	+.74**	
FID	+.65**	+.61*	+.66**	+.68**	+.84**

[1]n = 22
[2]n = 48
* Significant at $P<.05$.
**Significant at $P<.01$.
ADG = Average daily gain.
INT = Intake expressed as organic matter as a percentage of body weight.
DN = Diet nitrogen percentage.
FN = Fecal nitrogen percentage.
DID = Diet in vitro digestibility.
FID = Fecal in vitro digestiblity.

the procedures of Neter and Wasserman (1974). Differences between regression coefficients for vegetation types and years were tested using the t-test discussed by Neter and Wasserman (1974). Simple correlation coefficients were tested for significance using the t-test discussed by Steel and Torrie (1960). The equation of Stein (1945) discussed by Steel and Torrie (1960) was used to evaluate sample size required. The formula is as follows:

$$n = \frac{(t^2)(s^2)}{d^2}$$

In this formula n is the computed sample size, t is the tabulated t value for the desired confidence level and the degrees of freedom of the initial sample, d is the half-width of the desired confidence interval, and s^2 is the variance of the initial sample. The individual variances associated with cows and collections for each diet sampling period were calculated using a completely randomized analysis of variance as discussed by Steel and Torrie (1960). Cow and collection variances were then calculated by the formula of Steel and Torrie (1960):

$$s^2 = \frac{s_w^2}{nm} + \frac{s_a^2}{n}$$

In this formula S^2 represents the total variance, n represents the number of cows used for sampling, m represents the number of collections, s_a^2 is the sum of squares for cows, and s_w^2 is the sum of squares for collections. The number of cows needed for adequate sampling was calculated using s_a^2/n as the variance and the number of collections needed was calculated using s_w^2/nm as the variance.

Results and Discussion

Fecal in vitro organic matter digestibility (FID) and fecal nitrogen (FN) were more closely associated with average daily gains and intake than fistula sample in vitro digestibility (DID) or fistula sample nitrogen (DN) (Table 3). Strong relationships occurred between the diet and feces for N ($r^2 = .83$) and ID ($r^2 = .71$) (Table 2).

No differences ($P>.05$) were found between forest and grassland linear regression equations for diet and fecal relationships for either N or ID (Tables 3 and 4). Regression equations were not different ($P>.05$) between years on either vegetation type. Linear regression equations for the relationship between diet and fecal N compare well with those reported by other investigators (Table 3). Standard errors associated estimates for N and ID were 0.26% and 2.68% respectively, when the 2 vegetation types were combined (Tables 3 and 4). Therefore it appears that reasonable estimates on the ranges studied can be obtained for both cattle diet N and ID by fecal evaluation.

The addition of fecal ID as an independent variable with fecal N did not improve ($P>.05$) the regression equation for predicting DN. However, a multiple regression equation using FID and FN as independent variables improved ($P<.01$) the equation for predicting DID:

Table 3. Linear regression equations using diet nitrogen percentage as a dependent variable and fecal nitrogen percentage as a independent variable (y = a + bx).

Vegetation type	Regression characteristic				
	a	b	r^2	n	*Sxy*
Forest[1]	-0.276	+.855	.78	24	.29
Grassland[1]	-0.262	+.815	.88	24	.23
Forest and Grassland[1]	-0.269	+.835	.83	48	.26
Other Research					
Raymond (1948) sheep	-0.14	+0.795	—	—	—
Fels et al. (1959) sheep	+0.66	+0.928	.86	—	—
Mould and Robbins (1981)[3] elk	+0.77	+0.490	.97	11	—
Hinnant (1979)[1] cows	-0.11	+0.789	.88	4	—
Hinnant (1979)[1] steers	-0.09	+0.662	.90	4	—
Robbins et al. (1975) deer[3]	-3.43	+2.780	.57	7	—

[1]Data are on an organic matter basis.
[2]Forages containing a high soluble phenolic content were not included in the regression.
[3]Diets were dominated by browse high in soluble phenolic content.

$$DID = .659(FID) - 5.948(FN) + 28.48$$

The coefficient of determination (R^2) and standard error of the estimate (S_{xy}) for this equation were .83 and 2.43, repsectively.

Better regressions between fistula and fecal samples for both N and IVOMD may have resulted if fecal samples had been collected from fistulated cows rather than steers. An average of 4 cows and 5 collections (20 fistula samples) were needed to sample DN on the forest pastures with 90% confidence that estimate was 10% of the mean. In order to sample DN on the grassland pastures with the same level of precision, 4 cows and 4 collections (16 fistula samples) were required. A total of 4 cows and 2 collections (8 samples) were actually used. An average of 4 steers would adequately sample FN on either vegetation type. Wallace and Van Dyne (1970), on sandhill range in Colorado, reported that 3 steers would evaluate FN with 90% confidence that the estimate was within 10% of the mean. At least 4 cows and 4 collections (16 samples) were needed to sample the forest pastures for DID with 90% confidence that the estimate was within 10% of the mean. In order to sample the grassland pastures with the same level of precision, 3 cows and 3 collections (9 samples) would be required. A total of 8 and 11 fecal samples would adequately sample FID on the grassland and forest, respectively, with the same precision level. These data show that FN and FID of fecal samples can be estimated with much greater precision than DN or DID. Coefficients of determination may have been improved if more fistula samples had been collected during each sampling period. The reduced precision of fistula sampling also explains why FN and FID were better correlated with average daily gain and intake.

Our equations (Table 3) for N agree well with those of Raymond (1948) and Hinnant (1979). Mould and Robbins (1981) found that DN and FN were closely associated for elk except when the diet contained a high percentage of soluble phenolic compounds. FN is elevated by soluble phenolic containing species because they have protein complexing capabilities. Although grasses are low in soluble phenolics, many shrubs and forbs contain high percentages of these compounds. The phenolic problem may be solved by removal of these compounds using the neutral detergent solution of Van Soest (1967) although this has not been studied. The high correlation between DN and FN in the present study is attributed to the fact cattle were consuming grass dominated diets (Holechek et al. 1982 b,c). Most of the shrub and forb species that were important in these diets are considered to have low soluble phenolic concentrations. Data reported by Mould and Robbins (1981) indicate that species high in soluble phenolics must comprise over 25% of the diet before they appreciably elevate FN values.

Table 4. Linear regression equations using diet in vitro digestiblity as a dependent valuable and fecal in vitro digestiblity as an independent variable (y = a + bx).

Vegetation type	a	b	r^2	n	*Sxy*
Forest[1]	28.7	1.41	.67	24	3.13
Grassland[1]	26.9	1.47	.75	24	2.21
Forest and Grassland[1]	27.8	1.44	.71	24	2.68

[1]Data are on an organic matter basis.

Other research is limited on digestibility relationships between fecal and diet samples of ruminant animals. Hollway et al. (1981) and Arthun et al. (1982) found significant correlations between DID and FID of cattle consuming pasture forages. The study by Arthun et al. (1982) showed that diet and fecal ID were highly correlated ($r = .97$) when cattle were consuming grass diets, but the relationship was greatly reduced ($r = .41$) by the inclusion of an alfalfa *(Medicago sativa)* diet in the correlation. Feces digestibility is probably determined primarily by the quality of fiber the ruminant animal has consumed and to some extent by the N concentration of the diet. Grasses typically are low in cell contents and high in cell wall constituents relative to forbs and shrubs (Short et al. 1974). However, the fiber component of grasses is more digestible than that of forbs and shrubs because it has a lower lignin content (Smith et al. 1972). Therefore fecal digestibility of animals on forb and/or shrub dominated diets should theoretically be lower than that of animals consuming grass dominated diets of similar digestibility. This theory is supported by Arthun et al. (1982). They found cattle on bermuda grass *(Cynodon dactylon)* pasture had a DID of 62% with a FID of 23%. In contrast the same cattle fed alfalfa hay had a DID of 68% with a FID of 19%. In our investigation cattle were consuming grass dominated diets (Holechek et al. 1982 b,c) in most periods of study, which may explain the high correlation between DID and FID.

Several studies evaluating the relationship between diet digestibility and FN were reviewed by Holechek et al. (1982c). Their review shows that diet digestibility and FN are positively related although the strength of the association has varied greatly between studies. On the basis of recent research by Van Eys (1978) it appears that FN can give reasonable predictions of diet digestibility when the diet consists primarily of grasses and the objective is to compare relative digestibility between pastures. However, FN may be a poor predictor of digestibility when diets are high in browse which can have both a high lignin and N content. Soluble phenolic compounds in many browse species can further elevate FN values in relation to digestibility (Mould and Robbins 1981). In our study the correlation between DID and FN was much higher on the grassland than on the forest pastures ($r = .64$) ($r = .84$). Browse was always a minor component in diets from the grassland pastures

(Holechek et al. 1982b) but it was a major component in diets from the forest pastures in some periods (Holechek et al. 1982c). Our results support the contention that FN concentration is a satisfactory indicator of digestibility when ruminant diets consist almost entirely of grasses but FN is a poor indicator of digestibility of diets high in browse.

Our study is consistent with several other studies reviewed by Cordova et al. (1978) which have shown FN concentration is not a good single indicator of forage intake of range ruminants (Table 2). Intake was better correlated with FN on the grassland pastures ($r = .74$) than on the forest pastures ($r = .58$). On both vegetation types intake was more closely associated with FN than FID. Arthun et al. (1982) reported FN and FID explained 97% and 37%, respectively, of the variation in intake by cattle fed 4 pasture forages. Another recent study by Holloway et al. (1981) showed FN and FID accounted for 31% and 19%, respectively, of the variations in intake of several grass-legume mixtures fed to cattle. Their coefficients of determination were substantially improved for both FN ($r^2 = .44$) and DID ($r^2 = .31$) by using digestible dry matter intake as their dependent variable. In our study use of digestible organic matter intake as the dependent variable resulted in higher correlations for both FN ($r = .71$) and FID ($r = .65$). When FN and FID were used as independent variables in a multiple regression to predict digestible organic matter intake as a percentage of body weight the correlation coefficient was improved ($r = .78$). However the standard error of the estimate (S_{xy}) was .31%, which we consider too high for predictive purposes. Holloway et al. (1981) also found intake prediction equations could be substantially improved by including more than one fecal nutritive quality characteristic in regression models.

Conclusions

Several studies show that trends in ruminant fecal nutritive quality are associated to varying degrees with trends in diet quality and animal performance. Fecal sampling is relatively simple, quick, and inexpensive compared to fistula sampling or rumen sampling techniques that involve animal sacrifice. Our results indicate FN and DID are well related to diet quality and animal performance for ruminants consuming grass dominated diets. However, our review of the literature indicates a high forb and/or browse component in the diet can substantially lower these relationships. We believe more research is needed before nutritive analyses of the feces can be accepted as a tool for diet quality and animal performance evaluation of range ruminants.

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Cattle Diet and Daily Gains on a Mountain Riparian Meadow in Northeastern Oregon

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Abstract

Cattle weight gains, diet botanical composition, and diet quality on a riparian meadow range in the Blue Mountains of eastern Oregon were evaluated in the late summer and fall in 1976, 1977, and 1978. Pregnant yearling heifers were used to evaluate livestock performance. Esophageally fistulated cows were used to evaluate diet botanical composition and diet quality. Cattle diets showed little difference in botanical composition between periods or years. Grasses comprised an average of 80% of the diet during the 3 year period. Kentucky bluegrass *(Poa pratensis)* was the most important grass in cattle diets and had the highest percent cover on the study pastures. Cattle diet quality showed little change within or between years. Crude protein concentrations appeared adequate for cattle to gain .5 kg per day. However, estimated digestible energy concentrations averaged only 80% of that recommended by the NRC. Daily gains were erratic between and within years averaging .41 kg for the 3 years. Average daily gains on the meadow were better than or equal to those reported in other studies for upland and upland and meadow pastures at the Starkey Range for the same periods. Separate fencing and deferred grazing of mountain meadows could improve cattle performance and aid ranchers in gathering cattle at the end of the grazing season. In addition deferred grazing should result in pasture improvement and provide better habitat for nesting birds. The primary disadvantage of deferred use of meadows would be the cost of fencing.

Riparian mountain meadows are a highly productive and important forage resource in many parts of the western United States. These areas are of particular value to the public from the standpoint of water and recreation. They also provide important fish and wildlife habitat. A rapidly increasing demand for the previously mentioned products dictates that riparian mountain meadows must be managed more intensively in the future than in the past.

Under season long grazing riparian mountain meadows often receive excessive use even under light or moderate stocking rates because they are situated in low, flat areas with abundant forage and water (Roath et al. 1982). One way of eliminating this problem is separate fencing of riparian mountain meadows from surrounding uplands. A recent study by Kauffman et al. (1982) shows that delayed grazing of riparian meadows may reduce or eliminate adverse impacts of grazing on nongame wildlife. Restriction of livestock to upland areas in the early part of the grazing season would allow deferment of riparian mountain meadows and should result in subsequent improvement in their condition. This could also aid in gathering livestock at the end of the grazing season as livestock would be concentrated on accessible terrain. The effect of deferred grazing of riparian mountain meadows on cattle diet and performance has not been reported. The objectives of our study were to determine the botanical composition and nutritive value of the diet and cattle weight gains on a riparian mountain meadow in the Blue Mountains of northeastern Oregon.

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Experimental Site and Procedures

The study site was located on the Starkey Experimental Range and Forest 48 km southwest of La Grande, Ore. Moderately deep canyon drainages separating broad rolling uplands characterize the topography of the Starkey Range. Elevations range from 1,080 to 1,525 m. A description of the soils of the study area is given by Strickler (1966). The average annual precipitation is approximately 53 cm and comes as snow and rainfall in the winter and spring. There is sufficient summer rainfall to result in fall regrowth in approximately one year out of two. Precipitation at Starkey in 1976, 1977, and 1978 is presented in Table 1.

Two 10-ha pastures having the same grazing history were established in 1975. Vegetation composition and structure of the pastures was nearly identical. Vegetation of the pastures is quite diverse and typical of riparian meadows in the Blue Mountains (Ganskopp 1978). As the result of disturbance most of the original vegetation has been severely altered. Many of the riparian meadows have been reseeded to introduced pasture grasses one or more times. Kentucky bluegrass *(Poa pratensis)* presently dominates the understory of many of the meadows. Under pristine conditions tufted hairgrass *(Deschampsia caespitosa)* was the dominant grass. Dominant forbs on the meadows include cinquefoil (*Potentilla* sp.) and western yarrow *(Achillea millefolium lanulosa)*. Both of these forbs are increasers and cinquefoil is particularly unpalatable to cattle (Pickford and Reid 1948). A variety of shrubs is found in the meadows although common snowberry *(Symphoricarpos albus)* and black hawthorn *(Crataegus douglasii)* predominate. Common snowberry is an important forage species for cattle in the Blue Mountains but black hawthorn receives little or no use. Most of the species on the study area were perennials; thus, only slight variations were found in species composition among years. Cover data were pooled across pastures because the vegetation composition of the two pastures was similar (Table 2).

Table 1. Precipitation in cm at the Starkey Experimental Range and Forest.

Month	25 year $\bar{X}$	1976	1977	1978
January	6.48	6.86	1.02	5.08
February	4.27	2.29	2.54	4.06
March	4.57	2.54	2.11	3.56
April	4.42	5.08	2.79	6.68
May	5.44	4.39	4.80	4.01
June	4.72	3.71	1.83	3.12
July	1.57	.05	.13	2.54
August	2.01	6.86	7.42	3.43
September	2.72	3.71	9.42	4.11
October	4.52	2.67	3.76	7.11
November	5.66	4.06	7.75	4.06
December	6.68	0.00	9.40	3.20
Total	53.06	42.22	52.97	50.96

Table 2. Percent cover pooled by pastures of the primary forage species and their contribution by percent weight to cattle diets pooled by grazing periods and years. Pasture cover data are from Ganskopp (1978).

Species	Percent cover	Percent in diet
Kentucky bluegrass *(Poa pratensis)*	21	12
Sheep fescue *(Festuca ovina)*	6	8
Small fruited bulrush *(Scirpus microcarpus)*	5	8
Spike bentgrass *(Agrostis exarata)*	2	8
Timothy *(Phleum pratense)*	4	4
Meadow foxtail *(Alopecurus pratensis)*	4	5
Mountain brome *(Bromus carinatus)*	2	3
Idaho fescue *(Festuca idahoensis)*	4	8
Sedge (*Carex* sp.)	6	5
Rush (*Juncus* sp.)	5	3
Other grasses and grasslikes	8	16
Total grasses and grasslikes	67	80
Western yarrow *(Achillea millefolium lanulosa)*	2	2
Clover (*Trifolium* sp.)	1	2
Cinquefoil (*Potentilla* sp.)	6	0
Other forbs	4	8
Total forbs	13	12
Common snowberry *(Symphoricarpos albus)*	8	6
Black hawthorn (*Crataegus* sp.)	5	0
Willow (*Salix* sp.)	<1	0
Saskatoon serviceberry *(Amelanchier alnifolia)*	1	T
Wax currant *(Ribes cereum)*	1	T
Baldhip rose *(Rosa gymnocarpa)*	1	T
Other shrubs	3	1
Total shrubs	20	8

The two study pastures were adjacent to each other and enclosed with a 4-strand barb wire fence. Meadow Creek bisected each pasture. Cattle were grazed on the pastures from August 16 to October 10 in 1976, 1977, and 1978. The grazing season was divided into two 28-day periods which extended from August 16 to September 12 (late summer) and September 13 to October 10 (fall). The cattle were grazed the first 28 days on one pasture and then rotated to the other. Under this strategy each pasture was grazed in the late summer every other year.

Three esophageally fistulated cows were used to collect diet samples in all 3 years of study. In addition, 11 head of pregnant yearling heifers were grazed on the pastures. A moderate stocking rate was assigned after criteria developed by Skovlin et al. (1976). The performance of the 11 heifers on the pastures was evaluated by weighing without shrink at the onset of grazing and the end of each 28-day grazing period.

Every other week 2 collections were made with the fistulated animals. Fistulated cows were grazed continuously on the pasture under study in all periods. Two samples were collected from each cow on the same week on a biweekly basis. The collection procedure involved grazing the fistulated cows to various parts of the pasture and allowing them to graze freely until at least 1 kg of grazed forage was acquired. Esophageal fistula samples were dried in a forced air over at 40° C for 7 days and then ground through a 1-mm screen. Crude protein was determined by the Kjedahl technique to include nitrates. In vitro organic matter digestibility (IVOMD) was determined by a modification of the Tilley and Terry (1963) technique (Vavra et al. 1973). Acid detergent fiber (ADF) and lignin were determined by the permanganate method of Van Soest and Wine (1968).

Digestible energy (DE) values were predicted from IVOMD using the following regression equation developed by Rittenhouse et al. (1971): Mcal DE/kg DM = .039 (OMD) –.10.

The microhistological technique of Sparks and Malechek (1968) was used in botanical analysis of diet samples. Twenty microscope fields on each of 3 slides were examined at 100× for each sample.

A completely randomized design and a standard *F*-test were used for all statistical comparisons. Covariance analysis was used to determine the relationship among initial weights at the beginning of each period and average daily gains.

Results and Discussion

Cattle diets on the meadow showed little difference between years or periods (Table 3). During the 3 years of study, 24 grasses, 9 forbs, and 5 shrubs were found in cattle diet samples. When samples were pooled across years and periods, Kentucky bluegrass was the most important species in the diet (Table 2). During each year there was increased dietary consumption of grasses and decreased consumption for forbs and shrubs in the fall compared to the late summer. Studies on upland ranges at Starkey have shown a decrease in forb consumption with seasonal advance (Pickford and Reid 1948, Holechek et al. 1982a,b). Some grass regrowth was available in the fall in all 3 years of study, which may further explain the increase in grass consumption. Common snowberry was the only shrub of importance in cattle diets. Other studies on upland ranges at Starkey have shown this shrub is heavily used by cattle particularly during drought (Holechek et al. 1982a,b).

Table 3. The percent by weight of important species found in cattle diets in 1976, 1977, and 1978.

	1976		1977			
Species	Late summer	Fall	Late summer	Fall	Late summer	Fall
Kentucky bluegrass	12	15	10	8	12	15
Sheep fescue	7	6	7^a	13^b	7	6
Small fruited bulrush	10	6	9	6	8	6
Spike bentgrass	9	4	6^a	13^b	9	3
Timothy	5	5	2	3	5	5
Meadow foxtail	4	7	1	3	5	7
Mountain brome	T	4	2	3	T	4
Idaho fescue	6^b	12^a	4	7	6	11
Sedge	3	1	7	4	4	2
Rush	2	3	5	2	T	1
Other grass and grasslikes	17	23	19	23	17	26
Total grasses and grasslikes	75^a	86^b	72^a	85^b	72^a	86^b
Western yarrow	2	4	T	T	T	4
Clover	4	1	1	T	2	2
Other forbs	12	7	12	9	16	6
Total forbs	18^a	12^b	14	10	18^a	12^b
Snowberry	3	T	13	2^b	2	4
Other shrubs	4	2	1	3	8	T
Total shrubs	7	2	14^a	5^b	10^a	2^b

[a,b]Means with different superscripts within row and year are significantly different at the .05 level.
T = trace

Table 4. Average cattle diet chemical composition on an organic matter basis, in vitro organic matter digestibility, estimated digestible energy and average daily gains.

Item	1976		1977		1978	
	Late summer	Fall	Late summer	Fall	Late summer	Fall
Crude protein (%)	10.9	10.7	9.1	8.8	9.6	9.2
Acid detergent fiber (%)	59.3	61.2	56.9[a]	60.1[b]	57.3	59.0
Lignin (%)	15.3	16.9	11.8	12.1	15.4[a]	12.2[b]
In vitro OM digestibility (%)	51.6	55.4	51.8[a]	44.2[b]	51.4	50.1
Estimated digestible energy (Mcal/kg)	1.9	2.1	2.0[a]	1.6[b]	1.9	1.8
Average daily gains (kg/day) riparian meadow	+0.99[a]	+0.13[b]	+0.46[a]	-0.16[b]	-0.04[a]	+0.74[b]
Average daily gains (kg/day) seasonlong pasture[1]	+0.63	+0.66	+0.05	+0.31	+0.30	+0.55
Average daily gains (kg/day) upland grassland[2]	+0.41	+0.40	+0.08	+0.29	-0.40	+0.28
Average daily gains (kg/day) upland forest[2]	+0.51	+0.38	+0.72	+0.33	-0.37	+0.46

[a,b]Means within year with different superscripts differ at the .05 level.
[1]from Holechek (1980).
[2]from Holechek et al. (1981).

There were no consistent differences in cattle diet nutrient components and in vitro organic matter digestibility between late summer and fall (Table 4). Crude protein was lower ($P<.05$) in cattle diets in 1977 than 1976 or 1977. This is attributed to reduced precipitation in May and June in 1977 compared to 1976 and 1978. Total May and June precipitation values were highly correlated with diet crude protein values for the late summer ($r = 1.0$) and fall ($r = .99$)

Because forage intake was unknown, it was impossible to determine if cattle met their energy and protein requirements. The protein requirements recommended by the NRC (1976) indicate that 350 kg pregnant yearling heifers require a crude protein concentration of 8.7% on a dry matter basis for a .5 kg gain. This value can be made more comparable to data presented in Table 4 by dividing it by .9 which represents the average organic matter content of many forages. This gives a recommended value of 9.7% crude protein on an organic matter basis. The data in Table 4 suggest that crude protein concentrations in the diet were not a serious limitation to livestock performance. The NRC (1976) recommended digestible energy concentration for a 350-kg pregnant yearling heifer to gain .5 kg per day is 2.6 Mcal/kg of forage on an organic matter basis. Estimated digestible energy concentrations shown in Table 4 never exceeded 80% of this requirement. Digestible energy was evidently much more limiting to cattle performance than crude protein.

Cattle weight gains were erratic and there was no consistent difference between the summer and fall when years were compared (Table 4). Holechek (1980), in a separate study at Starkey, reported cattle diet quality and weight gains for season long unrestricted pastures (upland + riparian) near the meadow pastures during the same years (Table 4). Diet quality was slightly higher on the season long pastures compared to the meadow. Average daily gains on the season long pastures were not consistent to those on the meadow. These data show average daily gains on the meadow pastures are superior to those on the season long pasture in the late summer in two years out of three but the reverse was true for the fall period. There was no consistent differences between cattle gains on the meadow and cattle gains on upland forest and grassland ranges at Starkey (Table 4). Vavra and Phillips (1979, 1980) reported increased diet quality when cattle were turned on a riparian meadow in the Wallowa Mountains of Oregon. Daily gain of calves increased .2 kg per day while cows that were losing weight on upland range gained weight on the meadow.

From the standpoint of cattle weight gain and diet quality, there is no clearcut advantage or disadvantage to delayed use of riparian meadows in the Blue Mountains. Improved gains resulting from delayed use of riparian meadows appear to be both location and year dependent. Late season use of riparian meadows has benefits from the standpoint reduced livestock gathering problems and possible improved range condition. From a wildlife standpoint, bird nesting and small mammal reproduction would be completed so cattle effects would be minimal (Kauffman et al. 1982). The primary disadvantage would be the cost of fencing.

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Germination Responses of *Eysenhardtia texana* and *Leucaena retusa*

S.G. WHISENANT AND D.N. UECKERT

Abstract

Germination and radicle growth of kidneywood and little-leaf leadtree were greatest at 30° C but occurred under a wide range of temperatures. Germination and radicle growth of kidneywood seed did not differ over the pH range of 5 to 9. Germination of little-leaf leadtree was lower at pH 5 and 6 than at pH 7 to 9. Decreased water availability reduced germination and radicle length of both species; however, kidneywood seed germination was more tolerant of moisture stress than little-leaf leadtree. Seeds of both species maintained high viability for at least 42 months after collection. An impervious seedcoat prevents germination of little-leaf leadtree seeds until it is scarified. Results from these experiments indicated no significant germination problems will be encountered in attempts to establish these plants under field conditions.

Production of livestock and wildlife in much of the arid and semiarid areas of the world is limited because range forages are deficient in protein. Leguminous forage shrubs can potentially increase the quantity and quality of feed available in arid and semiarid areas. Woody legumes are less susceptible to seasonal droughts than are herbaceous species and can supplement animal diets during dry periods. The use of woody legumes to increase soil nitrogen and to provide high-protein feed well into the dry season has dramatically increased animal production in both humid and arid areas of the tropics (Jones 1979). This study was undertaken to evaluate the germination characteristics of two leguminous shrubs, *Eysenhardtia texana* Scheele (kidneywood) and *Leucaena retusa* Gray (little-leaf leadtree), native to arid and semiarid regions of Texas and Mexico, which are believed to have great potential as forage shrubs. This information on germination responses to simulated environmental parameters should identify any significant germination barriers to field establishment of kidneywood and little-leaf leadtree.

Kidneywood is a shrub which grows from 1 to 4 m tall on calcareous soils of South, Central, and West Texas and south into Mexico (Correll and Johnston 1970). In the drier areas of West Texas kidneywood is mainly found along dry arroyos (Warnock 1970). Kidneywood is considered an excellent browse plant for livestock and wildlife. Krausemann (1978) listed kidneywood as a food of desert mule deer *(Odocoileus hemionus crooki)* in Big Bend National Park in Texas. Anthony and Smith (1977) reported that desert southwest rangeland dominated by kidneywood *(E. polystachya)* was heavily utilized by deer during the hot, dry season, which is the most critical period of the year for desert southwest deer herds.

Little-leaf leadtree is a shrub or small tree which may grow to 5 m tall. It occurs principally on dry, well-drained, rocky soils in Central and West Texas and in Coahuila Mexico (Correll and Johnston 1970, Vines 1960). Little-leaf leadtree is readily browsed by wildlife and livestock (Lamb 1975, Vines 1960; Warnock 1977) and has been recommended as an ornamental (Vines 1960, Warnock 1977) because of its brilliant golden globose flowers. The Texas Organization for Endangered Species included little-leaf leadtree in a list of rare and endangered plants (Rowell 1975) of Central and West Texas. Little-leaf leadtree has many characteristics similar to the closely related but more tropical *L. leucocephala* (koa haole) which is widely used throughout the tropics for forage. It is one of the highest yielding, high-quality legumes of the tropics (Brewbaker et al. 1972, Jones 1979, Oakes 1968, Takahashi and Ripperton 1949). Sheep may shed their wool 1 to 2 weeks after beginning a steady diet of koa haole and continued feeding may result in death

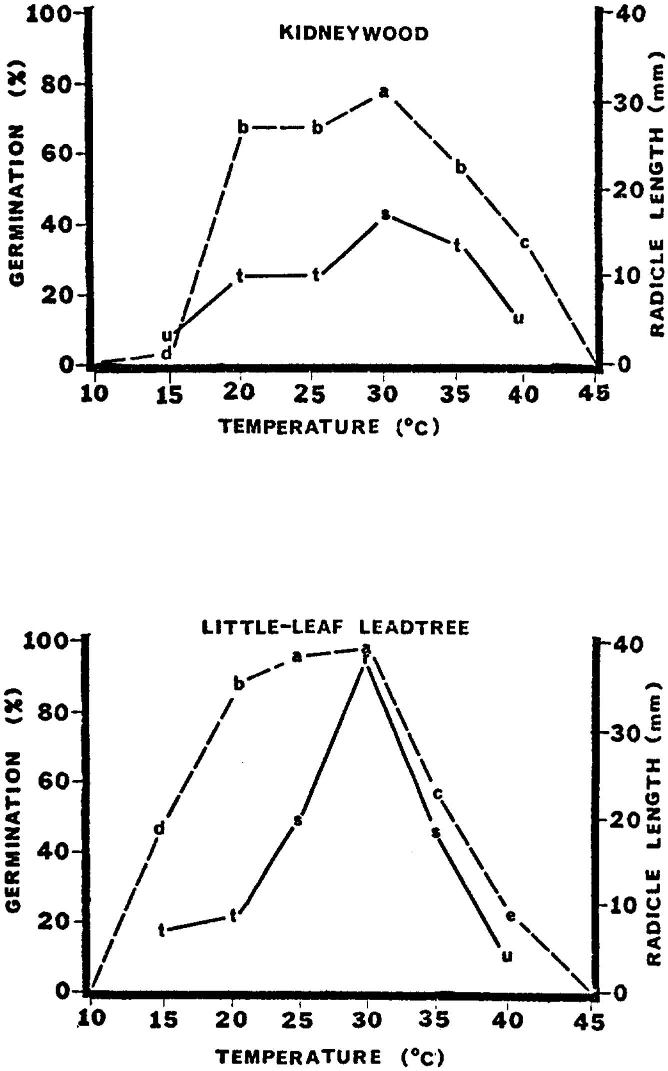

Fig. 1. *Germination and radicle elongation of kidneywood seed (top) and little-leaf leadtree seed (bottom) after 10 days at various constant temperatures. Germination response is indicated by a dashed line and radicle elongation by a solid line. Means with similar lower case letters are not significantly different at P<0.05.*

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due to a toxic amino acid (mimosine) found in all parts of the plant. However, this toxicity has not been observed under natural field conditions (Jones 1979).

Materials and Methods

Kidneywood and little-leaf leadtree seeds used in this study were collected during 1976 and 1978, from plants growing at the Soil Conservation Service Plant Materials Center at Knox City, Texas. Kidneywood plants at Knox City were grown from seeds collected near Uvalde, Texas, and little-leaf leadtrees were grown from seeds collected near Junction, Texas. Seeds harvested in 1976 were used to determine the length of viability and the 1978 accession was used for all other experiments. Seeds were stored at room temperature (24° C ± 3° C) until used in experiments. Seeds were tested for seed coat dormancy by comparing germination of untreated seeds with that of seeds which had the testa perforated with a scapel. Germination studies were conducted using 6 replications of 40 fully developed and undamaged seeds in 10-cm diameter petri dishes. Two Whatman No. 3 filter papers saturated with 7 ml (kidneywood) or 8 ml (little-leaf leadtree) of distilled water or various test solutions were used as the germination substrate. The petri dishes were randomly arranged on moist paper toweling in a sealed box inside an environmental chamber. Germination percentage and radicle length were recorded at the end of 10-day trial. Seeds were considered to have germinated when the radicle was at least 1 mm (kidneywood) or 3 mm (little-leaf leadtree) long. Each experiment was repeated 2 to 5 times and the data pooled for presentation.

The effect of constant temperature on germination and radicle elongation was evaluated at 5° ± 1° C increments between 10° and 45° C. All other experiments were conducted at 30° C. Light requirements were investigated by comparing germination of seeds in petri dishes covered with aluminum foil with that of seeds in transparent dishes. All other experiments were conducted under constant lighting from fluorescent and incandescent sources.

The effects of moisture stress on germination and radicle elongation were studied at 30° C using aqueous solutions of polyethylene glycol (PEG) 6000. The solutions were mixed by the method described by Michel and Kaufmann (1973) to exert osmotic potentials of -2, -4, -8 and -12 bars. Distilled water was used for the 0 bars treatment. The pH of these PEG solutions was 7.2

The effect of pH on germination and radicle elongation was investigated at 30° C by adjusting the hydrogen ion concentration of distilled water with HCL and KOH. This approach avoided the potential osmotic effects exerted by buffered solutions (Scifres and McCarty 1969). The change in pH of these unbuffered solutions was minimal (from 0.1 to 0.2 unit change). A range of pH values from 5 to 9 in whole unit increments was used.

The effects of age on seed viability was evaluated by germinating seeds at 3-month intervals from date of collection in 1976 to 42 months after seed collection.

Germination data were subjected to arcsin $\sqrt{P}$ (P = proportion germinated) transformation prior to conducting analyses of variance. No transformation was applied to radicle lengths. Differences among treatment means within an attribute were determined with Duncan's multiple range tests where appropriate.

Results and Discussion

One of the most important of the specific conditions that must be met during seed germination is temperature (Toole et al. 1956). The minimum temperature for germination of both species was 15° C with 2% and 44% germination of kidneywood and little-leaf leadtree, respectively (Fig. 1). The maximum temperature for germination of both species was 40° C with 35% and 9% germination of kidneywood and little-leaf leadtree, respectively. The optimum constant temperature for germination and radicle elongation of both species was 30° C. At 30° C, 75% of the kidneywood seeds and 99% of the little-leaf leadtree seeds germinated.

Germination response of kidneywood seed to moisture stress demonstrated an ability to withstand some stress without a significant decrease in germination. However, increasing moisture stress significantly ($P<0.05$) decreased radicle elongation of kidneywood seedlings (Fig. 2). Seed germination and radicle length of little-leaf leadtree seedlings were progressively reduced by increasing osmotic potential (Fig. 2). It is possible that the osmotic potentials of these solutions may have changed during the 10-day germination experiments because of evaporation from the petri dishes. However, placing the dishes on the moist towels in the sealed glass box should have minimized this possibility.

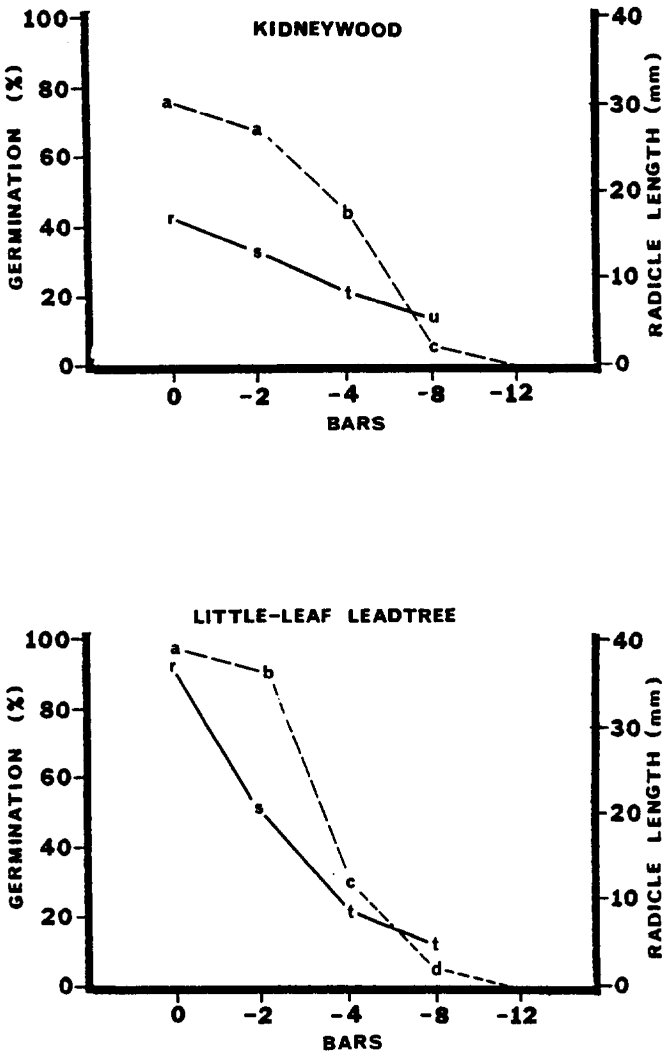

Fig. 2. *Germination and radicle elongation of kidneywood seed (top) and little-leaf leadtree seed (bottom) after 10 days at various moisture tensions at 30° C. Germination response is indicated by a dashed line and radicle elongation by a solid line. Means with similar lower case letters are not significantly different at* $P<0.05$.

There were no significant ($P<0.05$) differences in seed germination or radicle elongation of kidneywood seedlings at media pH values of 5 to 9 (data not shown). Little-leaf leadtree seed germination was favored by an alkaline medium and germination decreased with increasing acidity. Germination of little-leaf leadtree seed was higher at pH media values of 7 to 9 compared to pH values of 5 and 6. However, little-leaf leadtree radicle growth was not significantly different ($P<0.05$) among the pH treatments imposed (data not shown).

The ability of seeds to retain viability for prolonged periods without germination is one of the most important adaptive and survival properties of plants, allowing survival during adverse seasonal conditions and providing for the storage of seeds in the soil (Nikolaeva 1977). In the case of leguminous plants, the failure to germinate rapidly is often attributed to the impermeability of the seed coat to water. This impermeability is caused by the cuticle and an extensively developed layer of palisade cells (Nikolaeva 1977). Under natural conditions, alternating extremes of temperatures, microbial action and abrasion against soil particles erode the coat and increase permeability, thus permitting imbibition (McDonough 1977). Kidneywood seed germination was unaffected by nicking the testa with a scapel. However, this treatment increased germination of little-leaf leadtree seeds from 4% to 98%.

Neither kidneywood or little-leaf leadtree seeds required light for germination at 30° C (data not shown). Germination of kidneywood or little-leaf leadtree seeds did not decrease significantly from collection to 42 months post-collection (data not shown).

Conclusions

Kidneywood and little-leaf leadtree are leguminous shrubs with potential for increasing forage quality for livestock and wildlife during the hot, dry months in the arid and semiarid regions of the world. No significant germination problems were observed which would prevent successful establishment of either species in most field situations. With respect to germination and radicle growth, both species are tolerant of a wide range of temperature and pH. Optimum temperature for germination and radicle elongation of both species was 30° C; no germination occurred below 15° C or above 40° C. Germination and radicle elongation of both species decreased with increasing moisture tension but effects of pH were minimal within the range pH 5 to 9. Mechanical scarification increased germination of little-leaf leadtree seeds but not those of kidneywood. Neither species required light for germination and seeds of both species germinated as well at 42 months after collection as at 3 months after collection. The little-leaf leadtree produced stronger and more vigorous radicles than kidneywood under the conditions of this experiment. This more aggressive radical growth suggests that little-leaf leadtree may be more successful in seedling establishment than kidneywood. Monsen and Christensen (1975) indicated that slow developing shrubs are likely to succumb if weeds are not eliminated prior to seeding, and that shrubs with aggressive seedlings are especially desirable for rehabilitating rangelands.

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Use of Range Shrubs to Meet Nutrient Requirements of Sheep Grazing on Crested Wheatgrass during Fall and Early Winter

ROBERT OTSYINA, C.M. MCKELL, AND GORDON VAN EPPS

Abstract

This study considered the feasibility of supplementing crested wheatgrass (*Agropyron cristatum* Fisch.) forage with some common rangeland shrubs. The necessary proportions of shrub and grass in the diet to meet protein and energy requirements were calculated for gestating sheep during the late fall and early winter grazing season. Shrubs studied included fourwing saltbush *Atriplex canescens* Pursh. Nutt.), winterfat (*Ceratoides lanata* (Pursh Howell), rubber rabbitbrush (*Chrysothamnus nauseosus* ssp. *albicaulis*, (Nutt) Rydb.), and big sagebrush (*Artemisia tridentata* ssp. *vaseyana* Nutt.). The shrubs were consistently higher in both total and digestible protein than crested wheatgrass over the period of study. Fourwing saltbush and winterfat with 8.24 and 6.31% digestible protein, respectively, were found to be the most promising shrubs to be used to supplement the low protein content of crested wheatgrass for late fall grazing. To meet dietary requirements for gestating sheep would require a minimum of 56 to 69% of fourwing saltbush and winterfat respectively, in the diet. Sagebrush and rabbitbrush were lower in digestible protein content, 4.04 and 4.43%, respectively, and therefore could not be used alone with crested wheatgrass.

The widespread adaptability and extensive use of crested wheatgrass (*Agropyron desertorum* Fisch) and Fairway crested wheatgrass (*Agropyron cristatum* (L) Goertn) indicate their importance to the range livestock industry. Bleak and Plummer (1954) estimated that crested wheatgrass had been seeded on 404,858 hectares (1 million acres) in the Intermountain West. These monospecific seedings of crested wheatgrass have long been used on arid intermountain ranges to provide improved grazing during the spring and early summer with the possibility of some grazing in the fall (Frischknecht 1968). Some of the foothill ranges are also used for overwintering sheep and cattle with or without supplementation (Kearl et al 1971).

Following the onset of plant maturity these pure stands of crested wheatgrass are low or deficient in protein, carotene, and phosphorus and are insufficient to meet gestation requirements for sheep and cattle (Cook 1972, Rauzi 1975). At the same time, however, these grasses have a high energy value. In contrast, some common salt desert shrubs are high in protein, carotene, and phosphorus but are low in energy (Cook 1971). Limited research has thus suggested that mature grass forage plus palatable shrubs will provide an adequate and balanced diet, and improve the performance of sheep during the late fall and early winter periods (Cook and Harris 1968, Chatterton et al. 1971, Van Epps et al. 1971).

The objectives of this study were first to determine the nutrient content of selected shrubs and crested wheatgrass in the late fall and early winter (September to December) and to determine their nutrient deficiencies, especially protein for grazing sheep; second to determine individual plant productivities and the proportions of browse and crested wheatgrass that best meet the minimum nutrient requirements of sheep for gestation during the fall and early winter months with particular reference to protein and energy.

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Methods

All plants sampled in this study, except big sagebrush were at the Nephi Field Station. The Nephi Field Station is situated in central Utah about 12 km south of Nephi. The climate in the area of the station is characterized by cold winters and relatively warm summers. Normal precipitation is in the form of snow in the winter and limited rainfall in the spring and summer. The long-term average precipitation is 31.25 cm. Soil at the station is classified as Nephi silt loam and is deep and well drained.

Big sagebrush (*Artemisia tridentata* ssp. vaseyana Nutt. samples were taken from a native foothill range about 2 km east of Brigham City, Utah, on Highway 89-91 because plantings of the subspecies were not available at the Nephi Field Station. Average annual precipitation ranges from 30.5 cm to 40.6 cm and occurs mostly as snow in the winter. The vegetation of the area is predominatly big sagebrush and bluebunch wheatgrass *(Agropyron spicatum).*

Shrub plants included in this study were rubber rabbitbrush (*Chrysothamnus nauseosus* ssp. albicaulis (Nutt) Rydb), winterfat (*Ceratoides lanata* (Pursh) Howell), fourwing saltbush (*Atriplex canescens* (Pursh Nutt.), and big sagebrush.

Fifteen plants in each species were randomly selected from previously established plots at the Nephi field station and from a native stand at the Brigham City site. Each plant was divided into 4 approximately equal portions by tying a brightly colored string inside the crown at right angles to enable samples to be taken on the same plant at each harvest period. Current annual twig growth was clipped monthly using one quarter (1/4) of each plant from September to December. Two other plants not previously clipped were retained as controls to determine the effects, if any, of clipping on the protein content in subsequent months.

Crested wheatgrass samples were obtained from a mono culture pasture using a meter square quadrat. All samples were dried, weighed, and analyzed for crude protein content by the Kjeldahl method (Harris 1970). Protein digestibility coefficients appropriate for sheep and metabolizable energy values for the various plant species were obtained from the literature (Cook and Harris 1968). These coefficients were used to calculate sheep diets from values collected in this study. Digestibility coefficients could not be determined within the scope of the present study. Analysis of variance (Steel and Torrie 1960) was used to determine the existence of differences in nutrient content with time. Results were considered significant at $\alpha = 0.05$ unless otherwise stated.

Provisional diets were calculated using shrubs a basic protein supplement for balancing the nutritional requirements of gestating ewes during the winter period. Minimum requirements were based on the National Research Council (1975) recommendations for sheep.

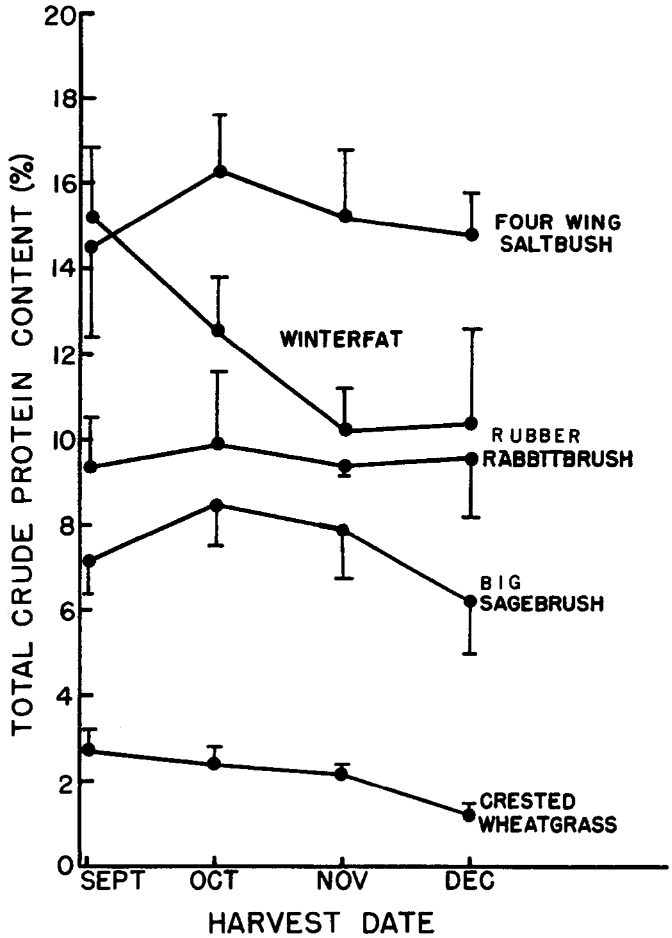

Fig. 1. *Changes in average crude protein content (%) of browse and grass from September to December. Vertical lines indicate half of the 95% confidence interval of the mean.*

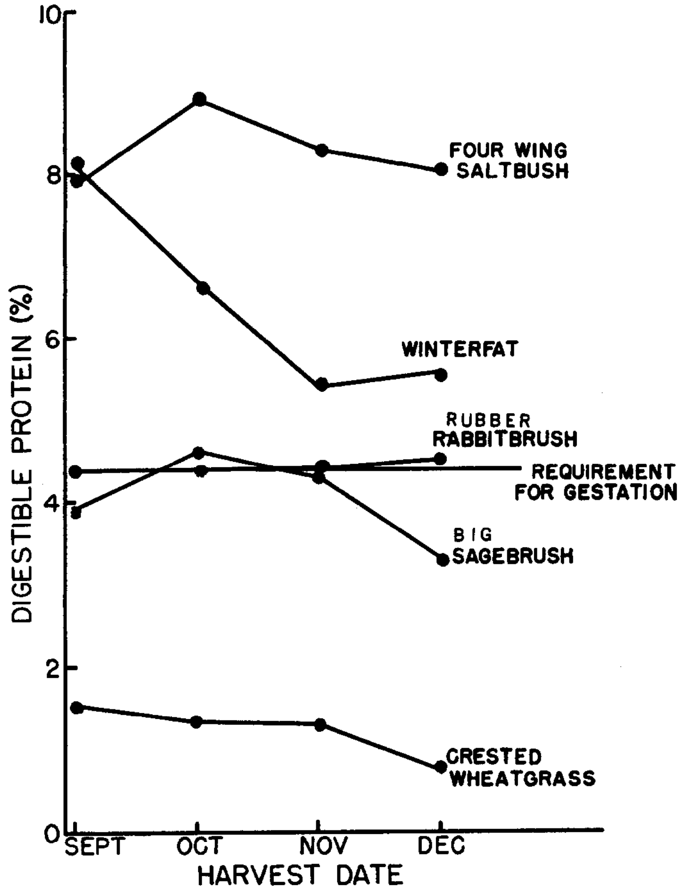

Fig. 2. *Calculated digestible protein content of browse and grass species in relation to the nutrient requirements for sheep under range conditions during the gestation period.*

In a preliminary grazing trial, 10 sheep were used to determine the effects of pure crested wheatgrass and a mixture of fourwing saltbush and crested wheatgrass on the liveweights after a 20-day grazing period. All animals were weighed before and after the trial. Observations on the grazing behavior in the 2 pastures were recorded.

It should be noted that the approach used in this study does not include all nutrients or effects of feed palatability and other factors that influence forage intake.

Results and Discussion

Production

Average annual production for the 4 shrub species sampled was 136.9, 213.0, 258.5, and 471.9 grams per plant for mature rabbitbrush, big sagebrush, winterfat, and fourwing saltbush plants, respectively. A similar high productivity of shrubs was also reported by Dietz (1972), who noted that 92 kg/ha of grazeable browse were produced in the fall by 6 shrub species on a deer range in the black hills of South Dakota. About 73% of the forage available to sheep during the winter season was from shrubs on Central Utah desert rangelands (Cook et al. 1954).

Post-cure average production of crested wheatgrass was found to be 128.8 g/m^2 (1,288 kg/ha). Because of the dormancy of the plants at this time, a high proportion of the herbage may be grazed without severe damage to the plants although some consideration must be given to having a plant residue to serve as a protection against soil erosion.

Nutrient Content

The total crude protein of shrubs was higher than crested wheatgrass at each of the harvest dates. Of all shrubs studied, fourwing saltbush had the highest crude protein content (Fig. 1). Although there were significant decreases in the crude protein content from September to December in all species except rabbitbrush, shrubs maintained an adequate protein content to meet the requirements of gestating ewes (Cook and Harris 1968, Cook 1972). In contrast, the crude protein content of crested wheatgrass decreased from 2.7% in September to 1.2% in December, much lower than most shrubs during the same period. The low protein content of crested wheatgrass at maturity observed in this study is similar to results reported by Sims et al. (1971). Malechek and Leinweber (1972) also noted a more consistent protein content in deep-rooted shrub species than in grasses and forbs in Texas.

Digestible protein values were calculated from the total crude protein data using digestibility coefficients obtained from Cook and Harris (1968).

Only fourwing saltbush winterfat exceeded digestible protein requirements of gestating sheep (Fig. 2). Rubber rabbitbrush and big sagebrush were very close to the digestible protein requirement for gestating sheep. Digestible protein appears to be the best single factor available to evaluate the nutrient quality of range forage (Cook et al. 1977). They noted that when the requirements for digestible protein are met by range forage for gestation and lactation, the requirements for energy, phosphorous, and carotene are usually met. This situation holds true only when the range vegetation includes adequate mixes of both browse and grass.

Metabolizable energy values for all plant species were obtained from the literature (Cook and Harris 1968). Crested wheatgrass, like many other grasses, was found to be higher in metabolizable energy content than any of the shrubs studied (Table 1).

Fourwing saltbush and winterfat appear to have a higher desirability than big sagebrush or rubber rabbitbrush as nutritional

Table 1. Average D.P. and M.E. contents of shrubs and grass compared to the minimum requirements for gestation.

	Dry matter basis	
	D.P. %[1]	M E[2] Mcal/kg
Requirement (60 kg ewe, gestation)	4.40	1.46
Test species		
Rubber rabbitbrush	4.43	1.67
Big sagebrush	4.04	1.27
Winterfat	6.31	1.40
Fourwing saltbush	8.24	1.42
Crested wheatgrass	1.23	1.87

[1]D.P. represents "Digestible Protein."
[2]ME represents "Metabolizable Energy" (Cook et al. 1968).

supplements to be interplanted with crested wheatgrass for sheep grazing during the dormant season (McKell 1975, McKell and Malechek 1978, Cook and Harris 1968).

Results of simple diet calculations using each shrub species alone plus crested wheatgrass indicated that sheep will require a minimum of 56% fourwing saltbush, 69% winterfat, and 99% rubber rabbitbrush in the diet to meet the minimum requirements for protein and energy (Fig. 3). These calculations were based onthe assumption that the shrubs are palatable and readily utilized by sheep in the mix pastures. Big sagebrush would be unsuitable due to its digestible protein values being lower than required by gestating ewes. In general, sheep diets on winter ranges in Utah contained about 70% browse and 30% grass (Cook and Harris 1968). The amounts of shrubs in the diet may be influenced by factors such as palatability and availability.

It was evident during the preliminary grazing trial that sheep readily browsed on fourwing saltbush as soon as they were introduced into the pasture. The relative preference indices of the various shrubs to sheep will be established in a subsequent trial. The calculated rubber rabbitbrush proportions needed seem unrealistic to implement due to the generally low palatability of rabbitbrush to sheep (Cook 1962).

In a preliminary grazing trial to determine the performance of sheep on pure crested wheatgrass and a mixture of fourwing saltbush and crested wheatgrass in the fall of 1979, sheep lost about 5% of their body weight on the pure grass pasture as compared with only 1% loss on the mix grass-shrub pasture during a 20-day grazing period.

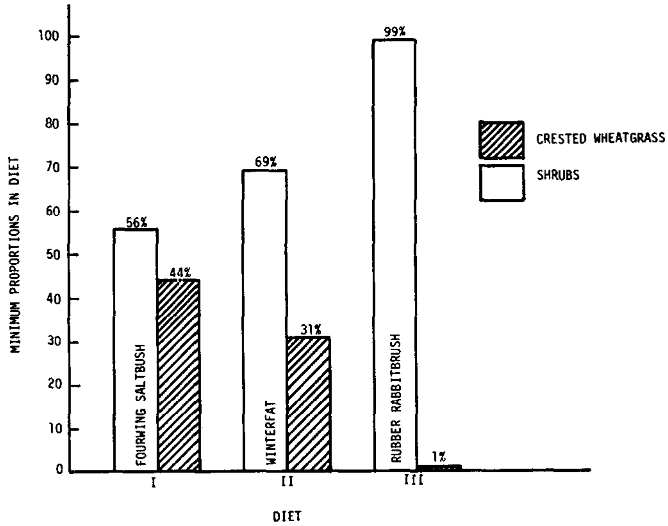

Fig. 3. *Required proportions of crested wheatgrass and shrubs in the diet to meet protein and energy requirements of sheep for fall and early winter grazing.*

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Biomass and Forage Production from Reclaimed Stripmined Land and Adjoining Native Range in Central Wyoming

ROBERT LANG

Abstract

Aboveground biomass and forage production from native range and adjacent reclaimed stripmined land were measured in 1977. On 2 of the 4 native range transects the aboveground biomass was greater than on reclaimed areas, largely due to big sagebrush and mat-forming species. Forage production, defined as the vegetation consumed by domestic grazing animals on properly grazed range, was equal to or greater on the reclaimed land than on adjoining native range.

Reclamation of stripmined lands is required by both the Wyoming Department of Environmental Quality and by recently (1977) enacted federal legislation. In both instances "production" of vegetation equal to, or greater than, that of the pre-mined condition is one of the requirements of the laws and regulations promulgated by the enforcement agencies.

Interpretation of the term *production* is variable. To some it means total aboveground biomass regardless of whether or not it is usuable by grazing animals, and to others it carries the connotation of "forage" that can be utilized.

During the summer of 1977 a study was initiated near Glenrock, Wyo., to compare biomass and "forage" production from undisturbed native range with that from adjacent lands which had been reclaimed after stripmining for coal production.

Description of the Area

The study area lies near the southern edge of the Powder River Basin. The native range is quite variable with some areas supporting almost pure stands of herbaceous species and others with variable stands of shrubs (primarily big sagebrush, *Artemisia tridentata)* and succulents or mat-forming species such as plains pricklypear *(Opuntia polyacantha)* and hooker sandwort *(Arenaria hookeri).* The most common vegetation type is sagebrush-grass and this type was selected for sampling to determine aboveground biomass and "forage" production.

In accordance with Wyoming laws, rules, and regulations, the topsoil is removed from the land prior to mining and is then spread over reshaped soil and seeded to reclaim the land to its previous major use, which in this study was for grazing of domestic livestock.

After the mining operation has progressed for a few years, there is a new acreage of mined-out land to be reclaimed each year. Sometimes the land to be reclaimed is ready for seeding in the fall and at other times it is not ready for seeding until spring.

Four areas of reclaimed land were sampled in this study. Area A was seeded in the spring of 1973 with a mixture of 9 lb of Fairway crested wheatgrass *(Agropyron cristatum),* 3 lb of western wheatgrass *(Agropyron smithii),* and 3 lb of thickspike wheatgrass *(Agropyron dasystachyum)* per acre. Five growing seasons had elapsed prior to sampling.

Areas B, C, and D were all seeded with 6 lb of Fairway crested wheatgrass, 6 lb of Nordan crested wheatgrass *(Agropyron desertorum)* and 3 lb each of western wheatgrass and thickspike wheatgrass per acre. From these figures it may be noted that the 1973 seeding was 60% and the 1975 seedings were 67% introduced species. Areas B and C were seeded in the fall of 1975 and only 2 growing seasons had elapsed prior to sampling. Area D was seeded in the spring of 1974, thus having completed 3 growing seasons prior to sampling.

Methods

Four transects, each 10 1-meter square plots, were established at random in the sagebrush-grass vegetative type which was the major native range type and 4 transects, each 10, 1-meter square plots on adjacent reclaimed land. One transect was established on each of the 4 reclaimed areas described above.

The vegetation within each meter square plot was clipped and bagged separately by species. Herbaceous species were clipped at ground level. Approximate current year's growth was harvested from sagebrush. All plant material was oven-dried at 70° C for 24 hours (excepting plains pricklypear, which was dried for 72 hours) *and then weighed to the nearest .01 gm.* These data were then converted to kg/ha to determine above ground biomass. To determine "forage" production, the biomass weight of each species was multiplied by its appropriate proper use factor[1] which considers what percentage of each species will be consumed by the major grazing animal species under proper utilization of these range resources.

Results and Discussion

Aboveground biomass from native range varied from 714.6 to 373.5 and averaged 570.9 kg/ha, largely in response to the amount of big sagebrush present on the harvested plots.

On the reclaimed areas the aboveground biomass varied from 861.1 kg/ha on land seeded in the spring of 1973, to 270.2 kg/ha on one of the areas seeded in the fall of 1975. Biomass data by vegetation groups are presented in Table 1.

Forage production as defined above, was calculated for both native range and reclaimed areas. On the native range the forage production from the 4 transects ranged from 137.1 to 113.0 and averaged 124.9 kg/ha. On the reclaimed lands the forage production ranged from 426.0 to 128.6 kg/ha. Data pertaining to forage production by vegetative groups are also presented in Table 1. It is interesting to note that the greatest aboveground biomass and the greatest forage production from reclaimed land were from areas seeded in the spring of the year (spring 1973 and spring 1975). The

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[1]Proper use factors used were those commonly used by SCS, that is, 50% of perennial grasses and 10% of big sagebrush. Cacti, mat-forming species, annual grasses, etc., are normally not used on properly grazed range.

Table 1. Average above ground biomass and forage[1] production from native range and from four adjacent reclaimed areas Glenrock, Wyo. Vegetation clipped in August, 1977. Data in terms of kg/ha oven dry.

	Native range		Area A-Seeded		Area B-Seeded		Area C-Seeded		Area D-Seeded	
Vegetation[2] groups	Biomass Wt	Forage Wt	Biomass Wt	Forage Wt	Biomass Wt	Forage Wt	Biomass Wt	Forage Wt	Biomass Wt	Forage Wt
Introduced perennial grasses	—	—	713.6	356.8	247.5	123.8	194.6	97.3	603.8	301.9
Native perennial grass and grasslike plants	197.9	99.0	138.3	69.2	9.6	4.8	63.8	31.9	27.8	13.9
Annual grasses	0.2	—	4.0	—	15.2	—	0.2	—	0.4	—
Big sagebrush	258.5	25.9	—	—	—	—	—	—	—	—
Forbs, halfshrubs and shrubs other than big sagebrush	114.3	—	5.2	—	17.5	—	11.6	—	23.0	—
Total	570.9	124.9	861.1	426.0	289.9	128.6	270.2	129.2	655.0	315.8

[1]Forage is considered to be the aboveground biomass consumed by domestic grazing animals under proper grazing management.
[2]All species encountered on native range and reclaimed areas are listed in Appendix A.

Table 2. Monthly and annual precipitation (inches) for the years 1973 through 1976 at Glenrock, Wyo. (5 E S E).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Departure Ann. from Nor.
1973	.84	.28	1.33	5.67	.90	.46	4.16	.35	5.43	.31	.59	.48	20.80 + 7.89
1974	.36	.57	.25	1.78	.30	.00	.50	1.00	.80	1.00	.56	.03	7.00 - 5.91
1975	.16	.25	3.02	.24	2.24	1.16	.54	1.07	.45	1.42	.31	.85	11.71 - 1.20
1976	.15	.39	.29	3.19	3.84	1.57	.67	.12	1.70	1.50	.09	.08	13.59 + .68

lowest were from the two areas seeded in the fall of 1975.

However, 1973 was a year with abundant precipitation, being nearly 8 inches above normal. 1975 precipitation was below normal for the year but precipitation from March through June was good. The areas seeded in the fall of 1975 would probably not have seedling emergence until the spring of 1976. Precipitation from April through June of 1976 was very good and the total for the year was .68 inches above normal. Monthly and annual precipitation data from 1973 through 1976 are presented in Table 2.

It was found that crested wheatgrass and desert wheatgrass, which varied from 60 to 67% of the seed planted on the reclaimed land, accounted for 83.2% of the biomass on all seeded areas and made up 86.4% of the total forage production.

On the native range big sagebrush was 45.3% of the total aboveground biomass and 20.7% of the forage production, whereas perennial grass and grass-like species were 34.7% of the total aboveground biomass and 79.3% of the forage production. From these figures it may be noted that slightly over 20% of the total aboveground biomass was from species that contributed nothing as forage because they are not utilized on properly grazed range.

From the forage production figures it is possible to calculate grazing capacity for both the native range and reclaimed land. Considering that 1 ton (2.24 metric T) of hay will support an animal unit for 3 months, it would require 302.7 kg of hay equivalent to furnish grazing for 1 animal unit for 1 month.

The average forage production of oven-dry material from the native range sampled was 124.8 kg/ha. With hay at 12% moisture, this would convert to 139.8 kg of hay equivalent per hectare. For 1 AUM 302.7 kg are required; thus the grazing capacity of the native range sampled would be 2.17 ha per AUM.

The same procedure applied to the reclaimed areas would show an average production from the 4 areas sampled to be 249.9 kg of forage per ha oven dry. This would convert to 279.9 kg of hay equivalent per hectare and an average grazing capacity of essentially 1.1 ha per AUM based on these averages.

Conclusions

From this study one may conclude that crested wheatgrass and desert wheatgrass are very well adapted to the area. On the reclaimed areas they furnished the greatest part of the aboveground biomass as well as forage production at least during the first 5 growing seasons after seeding. A number of native species are invading the seeded area. Only 3 species were seeded in Area A (the oldest seeded area) but 13 species were present when it was sampled. Four species were seeded and 7 to 10 species were present when the newest seeded areas were sampled. This species diversity compares with 12 as the highest and 8 as the smallest number of species encountered on the 4 transects in native range.

Spring seeded areas were more productive than fall seeded areas in this study. However, the results may have been due to precipitation and other climatic factors in the year of seeding and further comparisons of spring vs. fall seeding should be made before definite conclusions are drawn.

It may be concluded that if "production" is considered to be forage or grazing capacity, these types of land may be successfully reclaimed. However, when crested wheatgrass and/or desert wheatgrass are the major species, special management is required as both are utilized best in early spring and late fall. Areas which are predominately crested or desert wheatgrass may need to be fenced and grazed during their periods of optimum palatability particularly where they are a relatively small part of a total management area.

Appendix A

List of scientific and corresponding common names of species found on sample plots in this study.

Agropyron cristatum	Crested wheatgrass
A. dasystachyum	Thickspike wheatgrass
A. desertorum	Desert wheatgrass
A. elongatum	Tall wheatgrass
A. smithii	Western wheatgrass
A. spicatum	Bluebunch wheatgrass
A. trachycaulum	Slender wheatgrass
Arenaria hookeri	Hooker sandwort
Artemisia frigida	Fringed sagewort
A. tridentata	Big sagebrush
Astragalus spp.	Loco
Bouteloua gracilis	Blue grama grass
Bromus tectorum	Hairy chess
Carex eleocharis	Needleleaf sedge
Carex filifolia	Threadleaf sedge
Chrysothamnus vicidiflorus	Green rabbitbrush
Hordeum jubatum	Green foxtail
Koeleria cristata	Junegrass
Opuntia polyacantha	Plains pricklypear
Oryzopsis hymenoides	Indian ricegrass
Poa secunda	Sandberg bluegrass
Stipa comata	Needleandthread
S. viridula	Green needlegrass
Vulpia octoflora	Sixweeks fescue

Growth and Nonstructural Carbohydrate Content of Southern Browse Species as Influenced by Light Intensity

ROBERT M. BLAIR

Abstract

Three species of palatable deer browse (flowering dogwood, yaupon, and Japanese honeysuckle) were grown under 3 levels of light intensity: 100, 45, and 8% of full sunlight. After 4 growing seasons, dogwood and yaupon under 45% light were significantly taller, contained more growing points, and produced a larger foliar, stem, and root biomass than plants under other light regimes. Twig growth and biomass were generally poorest in full sunlight, whereas foliar and root biomass were poorest in deep shade. Leaves of all species were smallest on plants in full sunlight. The dry weight per unit of leaf area and the concentration of total nonstructural carbohydrates in leaves declined for all species as light intensity declined.

Of the environmental parameters affecting the growth of deer and livestock forage in the understory of forest stands, light is generally recognized as the most influential. With sufficient understanding of the influence of light on the survival, growth, and regeneration of palatable forages, silvicultural guidelines can be developed for objectively sustaining desirable light intensities in the understory with the least infringement on wood production. Currently, the production of forage is little more than a chance by-product of stand silvics.

The research reported here explored the effects of 3 levels of light intensity on the leaf, stem, and root growth and the total nonstructural carbohydrate levels in the leaves of 3 species of palatable deer browse that commonly occur in the understory of southern pine-hardwood forests. Data were collected from 1974 through 1977 in conjunction with a study evaluating the influence of light intensity on the nutrient quality and digestibility of browse leaves (Blair et al. 1982, unpublished manuscript).

Study Area and Methods

The study was conducted within the loblolly-shortleaf pine forest type on the Stephen F. Austin Experimental Forest near Nacogdoches, Texas. The principal tree species in the forest type are loblolly pine *(Pinus taeda)* and shortleaf pine *(Pinus echinata)* in association with assorted hardwoods. Characteristically, stands consist of a multitiered midstory of pines, hardwoods, and shrubs beneath a pine-hardwood overstory. The stand structure and composition generally result in heavy shading in the forage stratum.

The open and relatively flat study site supports well-drained sandy loam soils with a heavy clay subsoil. The soils are acid in reaction and contain moderate amounts of organic matter and natural plant nutrients.

Summers are hot and humid and winters are generally mild. The frost-free season averages about 243 days from mid-March to mid-November. A mean annual precipitation of 122 cm is generally well distributed throughout the year.

Spring growth of woody plants begins in late March or early April and twig elongation is nearly completed on most species in June (Halls and Alcaniz 1965). Limited growth also occurs on some species following summer rains, particularly after a prolonged dry spell, and on some broadleaf evergreens during warm winter periods.

The study site was plowed and leveled to reduce competing vegetation and 127.3- by 26.5-m plots were established in a 3 treatment by 4 replication design, each separated by a 15-m buffer.

Light intensities of 100, 45, and 8% of full sunlight were randomly assigned to treatment plots. Each intensity was replicated 4 times in a completely randomized design. For treatments designated as less than full sun, polypropylene fabric, woven to provide the prescribed light reduction was placed over a 2.4-m high wood frame covering each treatment plot. The bottom 0.3 m on the sides and the top 1.0 m on the end walls were left open to facilitate air movement. Light entry at the upper end-wall openings was controlled by a fabric-covered overhang. Shading was placed over the frames immediately before planting.

Browse species studied were flowering dogwood *(Cornus florida)*, a deciduous small tree, and yaupon *(Ilex vomitoria)*, a broadleaf evergreen shrub, both endemic, and Japanese honeysuckle *(Lonicera japonica)*, a common and widespread vine of Asiatic origin that is generally evergreen in the Gulf Coast Plain. These species are considered moderate in shade tolerance, with flowering dogwood the most tolerant. Dogwood and yaupon plants were 2-year-old container-grown nursery stock and honeysuckle plants consisted of young rooted leaders lifted from an extensive open area adjacent to the study site.

In February 1974, 1 16-plant row of each species was outplanted on each treatment plot. Species row assignments were random. Plants were spaced 1.5 m within a row and 2.4 m between rows. The long axes of plots were oriented northeast by southwest so all plants would receive approximately equal exposure to solar radiation. Honeysuckle growth was supported on 1-m high woven-wire trellises extending the full length of each row.

To eliminate gross differences in soil moisture, gypsum soil blocks were buried on each plot and water needs were monitored by periodic readings with a Bouyoucos soil moisture meter. Water was applied when a meter readout dropped to 45% available soil moisture at either a 6- or 12-inch depth. More frequent water was needed on plots in full sunlight and under 45% light than on plots under 8% light.

Plants used for growth measurements and chemical determinations were randomly selected. Beginning in the spring of 1976, after plants had grown 2 years under their prescribed light regime, and again in 1977, leaf samples were collected at mid-month of April, May, June, July, August, September, and December, to evaluate differences in the content of total nonstructural carbohydrates. Current leaf tissues were collected only from the terminal 10.2 cm or less of dogwood and yaupon twigs and 20.4 cm or less of honeysuckle leaders. Each month the leaf sample was obtained

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from 1 plant within a species row and individual plants were sampled only once yearly. Samples were collected between 10:00 a.m. and 2:00 p.m. to minimize diurnal fluctuations in sugar content of the cell sap.

Excised samples were immediately dried to a constant weight in a forced-draft oven at 60° C, ground in a Wiley mill to pass a 1 mm screen, and temporarily stored in a freezer. All leaf tissues were analyzed for total nonstructural carbohydrate (TNC) by the Agronomy Department, Virginia Polytechnic Institute and State University, Blacksburg. Determinations were according to procedures described by Wolf and Ellmore (1975). Reported TNC values are averages of the 1976 and 1977 measurements.

In September 1976 and 1977, 10 leaves of flowering dogwood, 15 of honeysuckle, and 20 of yaupon were collected from 1 plant per species on each treatment plot to determine the area and weight of the average size leaf. Selection of sample leaves was based on what appeared to be the typical size for the plant. Excised leaves were temporarily affixed, by species, to a paper backing then photocopied to obtain leaf imprints. The area of each imprinted leaf blade was determined by a polar planimeter. After imprinting, leaf samples were dried at 100° C in weighing bottles, desiccated until cool, then weighed to the nearest 0.1 mg. Leaf area and weight data were averaged for the 2 years.

In September 1974, 1975, and 1977, after 1, 2, and 4 growing seasons, respectively, under the prescribed light regimes the total height growth and the number of growing points (twig tips) were determined on 3 plants of dogwood and yaupon on each treatment plot. In addition, the total linear growth of current twigs was measured on these plants in 1977. In late October 1977, prior to leaf abscission, all leaves were collected from 1 plant of dogwood and 1 of yaupon on 1 random plot of each light treatment. Leaves were oven-dried to constant weight at 100° C to derive total leaf biomass. During early December 1977 the root systems of these 3 plants of each species were extracted from the ground using a hydrolic water procedure. The maximum diameter of the crown and root system was determined for each extracted plant, after which plants were fractioned into current stems, old wood, and roots. Each root system was dried at 60° C, and ground through the 1-mm screen of a Wiley mill, after which a weighed subsampled was removed for a total nonstructural carbohydrate determination. The remaining root and wood fractions were oven-dried to constant weight at 100° C.

For honeysuckle only total leaf growth was collected from 1 plant of each treatment as the intertwining leaders could not be removed from the wire trellises and the linear growth measured.

From mid-March through mid-November during measurement years, the maximum, minimum, and ambient air temperatures, soil temperature, and relative humidity were determined biweekly on 1 random plot of each light regime. Air temperatures were taken at 76 cm and relative humidity was taken at about 122 cm above ground. Soil temperature was measured by a probe thermometer inserted 7.6 cm below the surface at 2 points per plot.

Growth and nonstructural carbohydrate data were subjected to variance analyses to evaluate differences due to light intensity and to test changes in carbohydrate content of leaves across time. When significant differences among treatments occurred, means were compared by Duncan's multiple range test. Testing was at the $P<0.05$ level.

Results

Environment

Except for differences in light intensity, the microclimate and phenological development of species varied little between treatments. The average maximum and ambient air temperatures increased slightly with an increase in light intensity. Minimum temperatures tended to be inverse to the light level. The mean differential, however, for maximum and minimum temperatures between treatments did not exceed 3.5° C while ambient temperature did not differ more than 2° C. Differences in mid-day relative humidity between plots in full sun and those with only 8% light averaged less than 5 percentage units.

Soil temperature at a depth of 7.6 cm averaged 3.6° C cooler under 45% light and 4.8° C cooler under 8% light than soils exposed to full sunlight. The retention of soil moisture following rain or manual watering was inverse to light intensity.

Plant Growth

The phenological development of species varied little between light regimes. Twig elongation and refoliation began in the open and under 45% light at about the same time in late March, but was initiated 5 to 7 days later under 8% light. Tissue maturation and the cessation of twig growth was nearly completed in late May on plants in the open and under moderate light, whereas, growth continued an additional 7 to 10 days under low light.

In late autumn, dogwoods growing in 45% light retained at least half their leaf biomass up to 2 weeks after open-grown plants lost all leaves. Plants growing in only 8% light retained about half their leaves up to 3 1/2 weeks after leaves abscised from plants in the open. Some fresh leaves persisted to midwinter.

Plant growth form and vigor of all species differed noticeably between light treatments. Under 45% light, plants were more robust in growth form and appeared more vigorous than those in full sunlight or under 8% light. Honeysuckle plants appeared to be severely stressed after about 2 years growth under the low light level. Even though new leaders were initiated each spring a portion of the current leaf crop would turn yellow and abscise as the growth flush matured. Leaders would subsequently die back several cm. At the low level of light, plants were apparently unable to produce

Table 1. Variation[1] in the growth characteristics of plants grown under 3 levels of light for 4 years.

		1974			1975			1977		
		Light intensity			Light intensity			Light intensity		
Growth character	Species	100%	45%	8%	100%	45%	8%	100%	45%	8%
Plant height[2] (cm)	Flowering dogwood	79 a	86 a	94 a	132 b	208 a	180 a	173 c	267 a	229 b
	Yaupon	97 a	114 a	117 a	130 b	224 a	211 a	160 c	254 a	234 b
Growing points[2] (no.)	Flowering dogwood	60 a	54 a	57 a	145 b	232 a	195 a	243 c	539 a	319 b
	Yaupon	76 a	80 a	80 a	137 b	240 a	182 a	374 b	1,081 a	434 b
Current stem growth[2] (cm)	Flowering dogwood	—	—	—	—	—	—	1,615 c	6,251 a	3,012 b
	Yaupon	—	—	—	—	—	—	1,011 c	6,424 a	3,076 b
Maximum crown diameter[3] (cm)	Flowering dogwood	—	—	—	—	—	—	79	198	229
	Yaupon	—	—	—	—	—	—	86	218	190
Maximum root diameter[3] (cm)	Flowering dogwood	—	—	—	—	—	—	236	183	99
	Yaupon	—	—	—	—	—	—	163	135	81

[1]Growth values (row) for each year and species followed by a common letter are not significantly different.
[2]Mean of 9 random plants for each light treatment.
[3]One random plant of each species for each light treatment.

Table 2. Size and weight[1] of mature leaves grown under 3 levels of light[2]. Means of leaves collected in 1976 and 1977.

Light intensity	Flowering dogwood[1] Area/leaf (cm^2)	Wt/leaf (mg)	Wt/area (mg/cm^2)	Yaupon Area/leaf (cm^2)	Wt/leaf (mg)	Wt/area (mg/cm^2)	Japanese honeysuckle Area/leaf (cm^2)	Wt/leaf (mg)	Wt/area (mg/cm^2)
100%	40.7c	377.1b	9.4a	1.0c	14.2c	13.6a	9.8c	90.2b	9.2a
45%	89.6a	575.8a	6.4b	2.4b	25.4b	10.7b	21.7a	114.5a	5.3b
8%	66.6b	235.6c	3.6c	4.9a	28.6a	5.8c	14.8b	43.5c	3.0c

[1]Oven-dry weight.
[2]Values between light regimes (within a column) followed by the same letter are not statistically different.

sufficient photosynthate for growth and maintenance, hence, above-ground biomass progressively deteriorated.

Changes in the height growth of dogwood and yaupon plants and the number of growing points after 1, 2, and 4 growing seasons under the prescribed light treatments are shown in Table 1. Differences in plant growth between light regimes began to appear the second growing season (1975). Shaded plants were significantly taller and contained more growing points than those in full sun. By the fourth growing season (1977) both dogwood and yaupon plants growing under 45% light were significantly taller and contained a considerably larger number of growing points and more growth of current twigs than plants under other light regimes. Plants in full sun generally displayed the poorest trends in growth response except in 1977 when yaupon plants in full sunlight contained about the same number of growing points as those in 8% light.

In earlier research employing controlled levels of solar radiation, Logan (1965) reported growth responses for white and yellow birch *(Betula papyrifera* and *B. alleghaniensis)* and sugar and silver maple *(Acer saccharum* and *A. saccharinum)* that are closely similar to findings reported here. Phares (1971) also found that the height growth of red oak *(Quercus rubra)* seedlings was greater under a median light intensity (30%) than under full sun or low light (10%).

In this study the maximum crown diameter of plants in reduced light was over twice that of plants in full sun (Table 1). In contrast, the maximum diameter of root systems was larger on open-grown plants than on those in the shade.

Dogwood and honeysuckle leaves were largest on plants grown under 45% light and smallest on plants in full sunlight (Table 2). For example, the area of dogwood leaves was 120% greater in 45% light and 64% greater in 8% light than that of leaves grown in full sunlight. The relationship between the area of dogwood leaves and light intensity was closely similar for honeysuckle leaves. Yaupon leaf area was inverse to light intensity. Leaves which developed in 45% light were 2.4 times greater, and those in 8% light were 4.9 times greater in area than those in the open.

The dry weight per unit of leaf area declined significantly in all species as light intensity declined (Table 2). This illustrated the characteristic tendency for shaded leaves to be larger in size but thinner than those in the sun (Kozlowski 1971). However, shade-adapted leaves usually absorb light more efficiently than sun leaves, which influences their photosynthetic efficiency and their production of photosynthates (Kramer and Kozlowski 1960).

Foliar, stem, and root biomass tended to be substantially greater for dogwood and yaupon plants grown under 45% light than for plants grown at other light levels (Table 3). Plants in low light produced the least dry-matter weight of current leaves and roots while plants in full sunlight produced the least weight of current and old stem tissues. Leaf biomass on honeysuckle grown in full sunlight was 63% greater than that in 45% light and 1,517% greater than in 8% light.

Both the root/leaf and root/stem ratios were higher for dogwood plants in full sunlight than those in reduced light (Table 3). Ratios were similar for yaupon plants growing in the open and under 45% light but higher than for plants in 8% light.

Total Nonstructural Carbohydrates

The TNC concentration in leaves provides a comparative measure between light regimes of the products of current photosynthesis. When newly expanded leaves begin to produce carbohydrates they first use the products for their own growth and eventually export carbohydrates for growth to subtending internodes and other tissues (Kozlowski 1971).

From April to December TNC levels were highest for all species in leaves grown in full sunlight (Table 4). The concentration declined significantly as the intensity of light declined. With the maturing of tissues between mid-May and mid-June, TNC declined considerably in open-grown leaves. In leaves grown under reduced light the levels generally changed little during this period. The second sizeable change in TNC concentration occurred from late summer (September) to winter (December). The evergreen leaves of yaupon and honeysuckle contained substantially more TNC in winter than they did in late summer, whereas, the abscised and weathered leaves of dogwood contained considerably less TNC in winter than did the fresh leaves in late summer.

Table 3. Oven-dry biomass (g) of plant fractions[1] and the weight ratios between fractions after 4 growing seasons under different levels of light.

Plant fraction	Flowering dogwood 100%	45%	8%	Yaupon 100%	45%	8%	Japanese honeysuckle 100%	45%	8%
Current leaves	271	821	209	82	275	64	776	476	48
Previous year's leaves	—	—	—	17	149	132	—	—	—
Current stems	77	264	86	32	104	47	—	—	—
Old wood	736	1,892	870	327	1,512	698	—	—	—
Total above ground biomass	1,084	2,977	1,165	458	2,040	941	—	—	—
Roots	928	1,334	303	136	605	112	—	—	—
Root/leaf[2] ratio	3.4	1.6	1.4	1.4	1.4	0.6	—	—	—
Root/stem[3] ratio	12.1	5.1	3.5	4.2	5.8	2.4	—	—	—

[1]Based on 1 random plant of each species from each light treatment collected in 1977.
[2]Total leaves present on each plant.
[3]Current stems.

Table 4. Variations in the total nonstructural carbohydrate content (% of oven-dry tissue) of browse leaves grown under 3 levels of light in east Texas[1].

Species	% Light	Apr.	May	June	July	Aug.	Sept.	Dec.
Flowering dogwood	100	24.1 a	24.4 a	21.9 a	23.8 a	20.8 a	20.0 a	17.8 a
	45	18.2 b	18.9 b	18.2 b	17.2 b	15.5 b	16.4 b	14.9 b
	8	7.3 c	9.0 c	8.0 c	8.8 c	10.1 c	12.5 c	9.9 c
Yaupon	100	20.3 a	21.2 a	17.9 a	18.4 a	17.2 a	19.0 a	26.0 a
	45	15.7 b	15.4 b	13.8 b	16.2 b	15.4 b	14.9 b	23.0 b
	8	6.8 c	6.6 c	7.6 c	12.7 c	10.6 c	10.1 c	18.7 c
Japanese honeysuckle	100	25.0 a	23.6 a	20.6 a	18.4 a	18.6 a	21.4 a	25.0 a
	45	16.0 b	17.2 b	15.4 b	13.3. b	14.7 b	14.4 b	20.9 b
	8	10.7 c	11.4 c	11.6 c	10.3 c	10.4 c	9.4 c	15.7 c

[1]Values for each species and month combination (column) followed by a common letter do not differ statistically.

Based on one random plant from each light treatment in December, the TNC concentration in roots of dogwood and yaupon tended to decline as light intensity declined. Dogwood roots contained 16.0%, 15.5%, and 11.7% TNC under the respective light regimes of 100, 45, and 8% of full sunlight and yaupon roots contained 14.3%, 13.2%, and 11.7% for the respective light intensities.

Discussion

If a vigorous community of palatable deer browse is to be sustained beneath a forest stand, the stand must be managed in a manner that provides moderate to high light transmission to the understory. At best, average light intensity beneath an established stand would probably be no higher than 40 to 50% of full sunlight. Kramer and Kozlowski (1979) note that light transmission to the forest floor decreases rapidly as tree crown cover increases up to about 35%, but with further increase in crown cover light transmission decreases more slowly. Obviously, light available to the understory forage community would vary considerably with the age, structure, and botanical composition of the stand; illumination stands it may be as low as 1 to 5% of that in the open. Light levels of Light penetration is generally less in hardwood than in pine stands and decreases in pine stands as the hardwood component increases. For illustration, Kramer and Kozlowski (1979) noted that under open crowned, even-aged pine stands illumination at the forest floor may be only 10 to 15% of full sun and in hardwood stands it may as low as 1 to 5% of that in the open. Light levels of this low magnitude are not conducive to the sustained growth of palatable forage for deer and other herbivores. Shirley (1929) concluded that low light intensities in forests, which often do not exceed 20% of full sun, could support growth for a limited period but illumination is too low to ensure survival because root development is poor, and food reserves are inadequately assimilated. Vegetation beneath a forest canopy tends to disappear at light intensities below 4% of full sunlight (Shirley 1945).

After 4 growing seasons in deep shade, where the light intensity was only 8%, the height and twig growth of both dogwood and yaupon generally exceeded that of plants in the open, yet root biomass was comparatively low. Of further significance, the production of nonstructural carbohydrates was substantially less throughout the year in deep shaded leaves than in leaves grown under 45% to 100% full sunlight.

Total nonstructural carbohydrates, often referred to as total available carbohydrates, include all carbohydrates that can be used either directly or indirectly as a source of energy or as building material in the plant once they are broken down by enzymes. In most higher green plants the greater part of the TNC fraction is composed of sugars, fructosans, dextrin, and starch (Weinmann 1947). These water soluble carbohydrates are the primary source of energy readily available to plants for maintenance of vigor for survival, and for the production of new tissues.

The limited root systems that occurred on plants in deep shade were probably due to the fact that plants were unable to manufacture enough food to grow sufficiently extensive root systems for the absorption of adequate water and minerals during periods of deficient soil moisture (Kramer and Decker 1944). Adequate soil moisture was provided in this study and this undoubtedly minimized the stress of an unbalanced low root/shoot ratio in 8% light. In a natural and competitive forest community many plants with such low root/shoot ratios would probably die back, in part or in total, during periods of low soil moisture in the summer. Further, with the low root/shoot ratios evident for dogwood and yaupon growing in only 8% light, one can question how long the plants could have sustained growth even with adequate water. Honeysuckle was unable to sustain current growth after only 2 years in the low light intensity. Concurrent with tissue maturation in early summer a portion of the leaf biomass turned yellow and abscised, after which several inches of current leader growth died back each year.

The ratio between the water- and mineral-absorbing surface (roots) and the transpiring and photosynthetic surface (leaves) of a plant is an important factor in the growth of woody forages. A small root system limits shoot and leaf growth by curtailing the supply of water and minerals to the top, while reduction in the photosynthetic surface limits growth of roots by curtailing their supply of carbohydrates (Kramer and Kozlowski 1979). In general, this interaction, when in balance, tends to maintain a reasonably efficient ratio of roots to shoots, but desirable ratios can be disturbed by unfavorable factors such as the progressive loss of understory light in a forest stand.

Not only is a moderate to high intensity beneficial to the sustained growth of palatable browse forages in the understory, but, of equal importance, high light transmission appears to significantly enhance many of the desirable nutrient characteristics of forages. Leaf tissues of flowering dogwood, yaupon, and Japanese honeysuckle plants grown under 45% and 100% of full sunlight contained substantially higher levels of highly digestible cell solubles, digestible energy, and digestible dry matter in conjunction with lower levels of fibrous cell wall fractions than plants grown under 8% light (Blair et al. 1982, unpublished manuscript). Reduced light transmission, however, favored increases in the content of crude protein and phosphorus.

It is hoped that further studies will be undertaken to evaluate the influence of light on the growth and nutrient quality of other important forages in southern forests and to determine the light intensity that is associated with timber stands of different structure and composition. From the amassed findings, prediction equations can be developed by resource managers for estimating the quantity and quality of forages that can be sustained in the understory of different forest communities.

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Longleaf and Slash Pine Decreases Herbage Production and Alters Herbage Composition

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Abstract

An overstory or slash pine on the Palustris Experimental Forest in central Louisiana decreased herbage production as early as plantation age 17 for longleaf pine and plantation age 10 for slash pine. During the years of 1960 through 1975, from 80 to 85% of the variation in herbage production could be explained by the equations, $Y = 2094.75 + 10.10P - 106.98BA$ for longleaf pine and $Y = 1606.18 = 14.03P - 88.10BA$ for slash pine, in which Y = herbage production in kg/ha, P = April through October precipitation in cm, and BA = pine basal area in m^2/ha. Pinehill and slender bluestem were the principal herbaceous species on nonforested plots in 1975, while a mixture of forbs, pinehill bluestem, and other bluestem grasses were most common on forested plots. The study quantifies data on herbage production and botanical composition over time and suggests ways for the forest manager to evaluate timber and herbage tradeoffs.

Cutover southern forest ranges produce appreciable amounts of herbage until shading and competition from regenerated pines reduce understory herbs (Pearson and Whitaker 1974). In precommercially thinned stands of direct-seeded slash pine, herbage yield was related to timber density whether trees were uniformly distributed or crowded into strips and blocks (Grelen et al. 1972). Herbage production was closely associated with basal area of young southern pine plantations in central Louisiana (Wolters 1973) and southern Mississippi (Wolters and Schmidtling 1975). However, information for land managers that quantifies the forest and range resource interactions over time is scant.

This paper describes some timber-herbage relationships in longleaf and slash pine plantations from regeneration through the pole timber stage and reports a way for evaluating timber and herbage tradeoffs.

Study Area

The study site was on the Longleaf Tract, Palustris Experimental Forest, in central Louisiana. Before reforestation, this typical cutover longleaf pine range supported a dense stand of bluestem (*Andropogon* spp.) grasses (Duvall 1962). The area was grazed yearlong by one brood cow/8.1 ha from the mid-1950's until fenced in 1960 to exclude cattle. In early 1952, a portion of the site was reforested with longleaf pine and in 1956 with slash pine. Both species were planted on 1.83 × 1.83-m spacing. Soils, classified as Beauregard and Bowie, were intermingled throughout the area. Annual precipitation averaged about 145 cm with more than 7.5 cm each month. Yearlong temperatures averaged 18° C, and monthly temperatures ranged from 8° C in January to 25° C in July.

Experimental Procedure

Sixteen 0.16-ha square plots were established in longleaf and slash pine plantations in 1960. Four replications of the following treatments were randomly assigned to plots within each plantation: high, moderate, and low pine basal area prescriptions, and a control that had all pines hand-removed in June 1960. Basal area prescriptions in 1969 were 23.0 (high) 19.5 (moderate) and 16.1 (low) m^2/ha for slash pine, and 23.0 (high), 18.4 (moderate), 13.8 (low) m^2/ha for longleaf pine. Eleven of the 12 stocked slash pine plots and 6 of the stocked longleaf pine plots exceeded their basal area prescriptions in 1969, at which time the excess trees were harvested (Wolters 1973). In 1973, basal area prescriptions were changed to 19.5 (high), 16.1 (moderate), and 12.6 (low) m^2/ha for both plantations. Immediately before the 1973 harvest, slash pine stands averaged 25.9 m^2 of basal area/ha and ranged from 21.6 to 31.9 m^2; longleaf pine stands averaged 23.2 m^2/ha and ranged from 19.5 to 28.2 m^2. Because all stocked plots exceeded the 1973 basal area prescriptions, additional trees were harvested.

The longleaf pine plantation had been prescribe burned by headfire in January 1955 to control brown spot needle blight (*Scirahia aircola*). Both plantations were burned by controlled backfire every third year during March since 1960. The plantations were also burned by controlled backfire in March 1974 to reduce residual slash after timber harvest.

Vegetation samples were collected in a 0.04-ha square sampling unit centered in each 0.16-ha plot. All sampling units were surrounded by a 10.0-m wide isolation strip. Pine basal area was calculated from a complete inventory of all pines 2.54 cm or larger diameter-at-breast-height (d.b.h.) Herbage production was assessed by a pooled estimate from clipping eight systematically selected 0.47 by 0.47-m (0.22-m^2) quadrats on each 0.04-ha sampling area. Oven-dried herbage weights were converted to kg/ha. Pine basal area and herbage production were measured in November at 3-year intervals from 1960 through 1969 and annually thereafter through 1975. Herbage botanical composition was determined in 1960 and 1975.

Precipitation was measured approximately 1.6 km from the slash pine and 2.4 km from the longleaf pine plantation.

Treatment effects on herbage production were compared by Tukey's Test. Herbage relationships with pine basal area and precipitation as the independent variables were determined by regression analysis (Steel and Torrie 1960). Data on herbage botanical composition with unequal replication were compared by Scheffe's Test (Freese 1974). Differences at the 0.05 level of probability were considered significant unless otherwise indicated.

Results and Discussion

Herbage Production

Annual herbage production fluctuated markedly from year to year under all treatments and plantation species (Table 1). By comparing annual herbage production on control treatments I noted that, in the absence of a pine canopy, variables that fluctuate annually substantially affect yield. On the controls, production ranged from about 2100 kg/ha to nearly 3900 kg and herbage production increased as precipitation increased. In 1960, 1963, and

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1972, herbage production on the controls averaged about 2250 kg/ha, and April through October precipitation averaged about 60 cm. During 1973, 1974, and 1975, herbage production averaged in excess of 3400 kg/ha, and April through October precipitation averaged about 110 cm. Seasonal precipitation as well as herbage production was generally intermediate in all other years. Grelen and Lohrey (1978) reported that herbage production on longleaf pine plantations was correlated closely with seasonal rainfall.

Slash pine treatments began to depress herbage production significantly at plantation age 10 (1966); however, longleaf pine treatments did not reduce herbage production until plantation age 17 (1969). Forested treatments of either pine species generally produced less herbage than the controls. From the standpoint of range carrying capacity, therefore, longleaf pine plantations could be stocked equivalent to cutover range for approximately 17 years after pines are planted but slash pine plantations could be stocked at cutover range rates for only about 10 years after planting. Thus, herbage production on southern pine range may be influenced by a number of variables including pine species, plantation age, rate of growth, tree density, and other variables such as uniformity of tree distribution in the stand.

The combined value of herbage and timber outputs from young unthinned plantations may be similar. For example, the annual basal area increment growth was less for longleaf pine than for slash pine (Wolters 1973). Similarly, in Mississippi, Schmidtling (1973) reported substantially greater cordwood volume growth in young slash pine plantations than in longleaf pine plantations. Therefore, returns from the higher rate of herbage production from grazed young longleaf pine plantations at least will partially offset the greater value of cordwood growth in young slash pine plantations.

Herbage production response to thinning in 1969 was small and short-lived at best. In 1970, for example, production appeared to increase slightly on all stocked slash pine treatments but in 1971, production declined nearly to or below the 1969 prethinning levels. However, only light thinning was necessary to reduce stocked longleaf pine stands to their basal area prescriptions in 1969. As a result, herbage production did not increase in 1970, but continued its downward trend. The selective thinning in 1969 consisted primarily of removing closely spaced, suppressed trees in both plantations, although a few diseased dominant trees were removed. A more uniform and longer lasting response in herbage production probably would have been obtained with the 1969 thinning if only dominant trees had been harvested.

Herbage production nearly doubled in 1974 after an intensive thinning in 1973. Production was even greater in 1975 than in 1974 due partially to the nearly 50% greater seasonal rainfall in 1975 and further recovery from the 1973 site disturbance. Herbage production after thinning appeared to have peaked in 1975 and slowly declined during successive years as competition with the pine stands increased; however, supportive data were not collected after 1975.

Herbage production is adversely influenced by competing vegetation on forested range. Local environmental factors also affect herbage production. Regressions were fitted to the present data to illustrate the relationship of herbage production to precipitation and/or pine basal area; however, the equations may not necessarily show the basic cause and effect of the relationship. The relationship of the present herbage production, pine basal area, and precipitation data can be expressed by the equations $Y = 2094.75 + 10.10P - 106.96BA$ for longleaf pine and $Y = 1606.18 + 14.03P - 88.10BA$ for slash pine, in which Y = herbage production in kg/ha, P = April through October precipitation in cm, and BA = pine basal area in m^2/ha. The equations, in which $N = 160$, explained 85% of the variation in herbage production in longleaf pine plantations and 80% in slash pine plantations. Standard error of the estimates was 414.42 kg/ha for longleaf pine plantations and 488.16 kg/ha for slash pine plantations. All equations used data of April through-October precipitation which ranged from 53.6 to 125.7 cm. Basal area data of stocked treatments ranged from 1.86 to 28.31 m^2/ha for longleaf pine and 1.01 to 31.89 m^2/ha for slash pine.

Precipitation contributed significantly to the explanation of variation in the dependent variable in both equations but basal area alone explained 80% of the variation in herbage production under longleaf pine and 71% of the variation in slash pine. The simple linear equations, with pine basal areas as the independent variable, were $Y = 2853.58 - 102.25BA$ for longleaf pine and $Y = 2690.92 - 84.66BA$ for slash pine. Standard error of the estimates was 472.68 kg/ha for longleaf pine and 583.82 kg/ha for slash pine.

Regression coefficients calculated from the present data sets with basal area as the independent variable are similar to the simple linear regression coefficients reported earlier by Wolters (1973) if the influence of precipitation is considered. For example, seasonal precipitation during this study averaged about 20% more than that reported for the earlier study. Grelen and Lohrey (1978) presented a linear equation relating herbage yield to longleaf pine basal area. After converting the Grelen-Lohrey equation to metric units, the regression coefficients were substantially smaller than those calculated for the present data. Differences resulting from precipitation, inherent site quality, and related physical factors may account for the large differences in regression coefficients.

Because our present state of knowledge does not permit us to accurately predict seasonal precipitation, the forest manager's primary consideration is to decide on the level of multiple resource outputs desired. Maximizing either herbage or timber essentially eliminates the other resource, although at intermediate pine basal area levels (12.5 to 21.0 m^2/ha) from 800 to 1600 kg/ha of herbage can be produced annually. Using information from this study the manager or landowner can apply present or projected values to herbage and timber yields when assessing the most appropriate mix of resource outputs.

Table 1. Herbage production (kg/ha) on longleaf and slash pine range, by prescribed basal area treatment and year.

	Slash pine basal area				Longleaf pine basal area			
Year	High	Moderate	Low	Control	High	Moderate	Low	Control
1960*	2401a[1]	2153a	1998a	2094a	1994a	2360a	2218a	2379a
1963*	1394a	1760a	1620a	2242a	1945a	1708a	2067a	2236a
1966*	874b	1176b	908b	2813a	1802a	1994a	2073a	2600a
1969	341b	649b	396b	2970a	791b	1206b	1403b	2973a
1970	399b	801b	745b	2267a	498b	555b	1329b	3353a
1971	204b	395b	519b	2462a	240c	447bc	615b	2715a
1972	364b	399b	604b	2168a	193b	262b	619b	2304a
1973	347b	499b	414b	3336a	352b	418b	832b	3450a
1974	1283b	1268b	661b	3250a	688b	1003b	1363b	3478a
1975	2190b	2385ab	2387ab	3683a	1049b	1445b	1661b	3853a

[1]Means within years and species of pine followed by the same letter are not significantly different at the 0.01 level.
*Values are from unthinned plantations.

Table 2. Botanical composition (%) of longleaf-slash pine range in 1960 and in 1975 under various pine basal areas levels.

Species	1960 (N=32)	1975 High (N=8)	1975 Medium (N=8)	1975 Low (N=8)	1975 Control (N=8)
Pinehill bluestem	26.3ab[1]	20.2b	33.8ab	31.7ab	42.0a
Slender bluestem	24.6a	4.2b	7.5b	4.9b	18.0a
Other bluestems	8.1a	15.2a	8.0a	18.0a	4.5a
Panicums	13.2ab	23.1a	14.8ab	10.1ab	4.1b
Other grasses	23.4a	11.2b	13.9b	14.9b	23.9a
Forbs	4.4b	21.1a	22.0a	20.4a	7.5b
Total	100.0	100.0	100.0	100.0	100.0

[1]Like subscripts in rows indicate no significant difference at the 0.05 level of probability.

Botanical Composition

Botanical composition of herbage by weight, at 3-year intervals from 1960 through 1969, was reported earlier (Wolters 1973). Because differences in herbage botanical composition from forested and control treatments were not discernible in 1970, all observations (N=32) were pooled. Similarly, differences in 1975 botanical composition were not discernible between tree species and, therefore, botanical composition data were pooled by prescribed basal area treatment. The 1960 and 1975 pooled estimates were compared to determine the effects of treatment and time on botanical composition.

Pinehill bluestem *(Andropogon scoparius* var. *divergens)* and slender bluestem *(A. tener)* each produced about one-fourth of the total herbage in 1960, and their proportions did not change significantly on the control in 1975 (Table 2). However, treatment levels influenced their proportions in 1975. Pinehill bluestem was found in greater proportions on the control than on the high basal area treatment and all treatments stocked with pine in 1975 depressed the proportion of slender bluestem herbage. Pinehill bluestem is a vigorous competitor on nongrazed range, but the vigor of slender bluestem was apparently reduced by nonuse, particularly under moderate to dense pine canopies. Similar responses of pinehill and slender bluestems to nonuse were reported by Grelen and Duvall (1966), Duvall and Linnartz (1967), Wolters (1973), and Grelen and Lohrey (1978).

The other bluestems, primarily big *(A. gerardi)*, Elliott *(A. elliottii)*, fineleaf *(A. subtenuis)*, paintbrush *(A. ternarius)*, and broomsedge *(A. virginicus)*, did not change in proportion from 1960 to 1975, regardless of the treatment imposed. Big bluestem, however, generally increased on forested treatments and particularly under slash pine where it occurred in large scattered clumps. Big bluestem was the only species of this group that sustained or increased its proportion under a pine canopy.

In 1975, panicums (*Panicum* spp.) were found in greater proportion under the high basal area treatment than on the control, although the proportion of panicums on forested treatments in 1975 did not differ from the 1960 pooled estimate. Switchgrass *(P. virgatum)* was the most abundant species of the panicum group under a high pine basal area, and the proportion of low panicums generally increased with reductions in pine basal area.

The other grasses, consisting primarily of paspalums (*Paspalum* ssp.), cutover muhly *(Muhlenbergia expansa)*, green silkyscale *(Anthaenantia villosa)*, and arrowfeather threeawn *(Aristida purpurascens)*, produced the same proportion on the control in 1975 as in 1960. However, the proportion of other grasses diminished under all forested treatments in 1975.

Forb composition was similar on the control in 1975 as in 1960; however, forbs increased under forested treatments. Poor-joe *(Diodia teres)*, white eupatorium *(Dupatorium album)*, and southern bracken *(Pteridium aquilinum* var. *pseudocaudatum)*, were the principal forbs on forested sites; grassleaf goldaster *(Heterotheca graminifolia)* and swamp sunflower *Helianthus angustifolius)* generally were the most abundant on the control.

The conversion of pinehill-slender bluestem range to a bluestem-forb range with reforestation enhances herbage diversity and may lengthen the green herbage season. The response of herbivores, however, to increased forbs in terms of daily consumption, nutritive value of diets, and animal weight change has not been determined.

Conclusions

Longleaf pine plantations can be stocked with cattle equivalent to cutover range for approximately 17 years after planting of pines, but slash pine plantations can be stocked only about 10 years after planting before a significant decrease in herbage production occurs. However, herbage productivity can be partially restored by intensively thinning the pine stand periodically.

Herbage production was correlated with seasonal rainfall; it increased as precipitation increased. Herbage production decreased as pine basal area increased.

In this study, regression equations explained 80 to 85% of the variation in herbage production on both longleaf and slash pine plantations. These data, along with herbage botanical composition information, can aid the land manager in evaluating timber and herbage tradeoffs for obtaining the best returns from his land.

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Early Succession Following Clearcutting of Aspen Communities in Northern Utah

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Abstract

Changes in aspen reproduction and undergrowth production and composition were recorded over a 3-year period following clearcutting. Aspen suckers increased from 2,300 per hectare prior to cutting to a maximum of 44,000 per hectare the second post-cut year, and dropped to approximately 25,000 per hectare by the third year. Undergrowth production on the cut units increased from 1,013 kg/ha prior to cutting to 3,000 kg/ha after three growing seasons; production on the uncut control areas increased from 1,199 kg/ha to 1,539 kg/ha during this period. The significant increase in undergrowth is attributed to the reduction in competition from the removal of the aspen overstory. Clearcutting appeared to increase the proportion of shrubs in the undergrowth and decrease the proportion of forbs. A similarity index comparing the cut and uncut areas suggested that the greatest change in species composition occurred the first year after cutting, with a gradual return towards the precut conditions.

The extensive aspen *(Populus tremuloides)* forests found at intermediate elevations in the intermountain Rocky Mountain West are highly valued multiple-use lands. They are noted for production of livestock forage, wildlife habitat, and scenic beauty, and they are a potentially valuable source of wood products. Through the process of natural plant succession many of these forests are becoming dominated by conifers, frequently within a single aspen generation. Such conversion concerns resource managers because it is usually accompanied by substantial reductions in forage and wildlife habitat. As a consequence, considerable interest has developed in periodically setting back the process of succession in order to maintain communities that are dominated by aspen.

Prescribed burning and clearcutting are the 2 main management alternatives for halting succession to conifers and regenerating the aspen forest. Both of these methods involve drastic disturbance of the plant community. Intelligent use of either requires that we understand not only the effect of such disturbance upon the trees, but upon other components of the community as well.

Burning is a viable alternative for rejuvenating an aspen forest where fuel conditions are amenable to fire and where the trees have little or no commercial value. Recently we published descriptions of early succession following prescribed burning of aspen communities (Bartos and Mueggler 1981). Clearcutting may be desirable either where burning is not feasible or where the value of the wood is sufficient to finance the cutting operation. Although the ability of western aspen to reproduce prolifically following clearcutting is well documented (Jones 1975, Schier 1976, Schier and Smith 1979), very little information is available regarding the changes in undergrowth likely to occur when the tree overstory is removed by clearcutting.

This report describes aspen reproduction and changes in undergrowth composition and production over a 3-year period following clearcutting aspen communities on the Wasatch National Forest in northern Utah.

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Methods

The Chicken Creek study site is located at an elevation of 2400 m on the Davis County Experimental Watershed approximately 12.4 km northeast of Salt Lake City, Utah. The site is dominated by aspen, with a lush understory of forbs and graminoids (Fig. 1) and has not been grazed by domestic livestock for the past 50 years. The main reason for selecting this particular site for cutting was to determine the effects of clearcutting aspen on streamflow rather than to set back conifer invasion. The streamflow information will be reported separately. The site has very deep clayey soils that have good water-holding capacities and the average yearly precipitation is 115 cm with 80 percent occurring as snow (Johnston and Doty 1972); the overstory tree component was described by Bartos and Johnston (1978). Although conifers were not actively invading the aspen, the cuttings provided an opportunity to study early successional trends following the cutting of aspen-dominated communities.

Eleven and one half hectares of aspen were clearcut in 5 separate blocks in the west branch of Chicken Creek. The study areas occupied northeasterly, northerly, and westerly exposures. The cut blocks were separated by uncut strips of aspen forest, which served as a control in evaluating the effects of cutting on the vegetation. Eighteen permanent 10 × 10 m macroplots were established in 1973 prior to cutting. These sample plots, including a 5 m border, were placed only on areas of uniform vegetation and topography. Nine macroplots were distributed in 4 of the cut blocks and paired with 9 other macroplots with similar vegetation and topography in adjacent uncut areas.

Vegetative production was measured at its peak in early August of 1973, the areas were clearcut in 1974, and the vegetation was

Fig. 1. *A general view of the Chicken Creek study site showing a lush undergrowth of forbs and graminoids.*

measured again at its peak in 1975, 1976, and 1977. Production was determined by double-sampling 48 microplots, 30.5 × 61 cm in size, systematically distributed within and adjacent to each of the macroplots. Capacitance meter readings (Currie et al. 1973) were obtained on each microplot; 10 of these microplots on each macroplot were then clipped by species to determine percentage composition. Regression equations developed for total production from only those plots both metered and clipped permitted conversion of all meter readings to herbage production. All clipped materials were dried to a constant weight (70° C for at least 48 hrs). Percentage composition by species was then applied to total production data to yield dry weight by species and vegetation classes.

Permanent subplots each 4 m² were located within the corners of each macroplot. These subplots were used to count the number of aspen suckers in 1973. In subsequent years, sucker numbers were counted on the entire 100 m² macroplots to obtain greater accuracy.

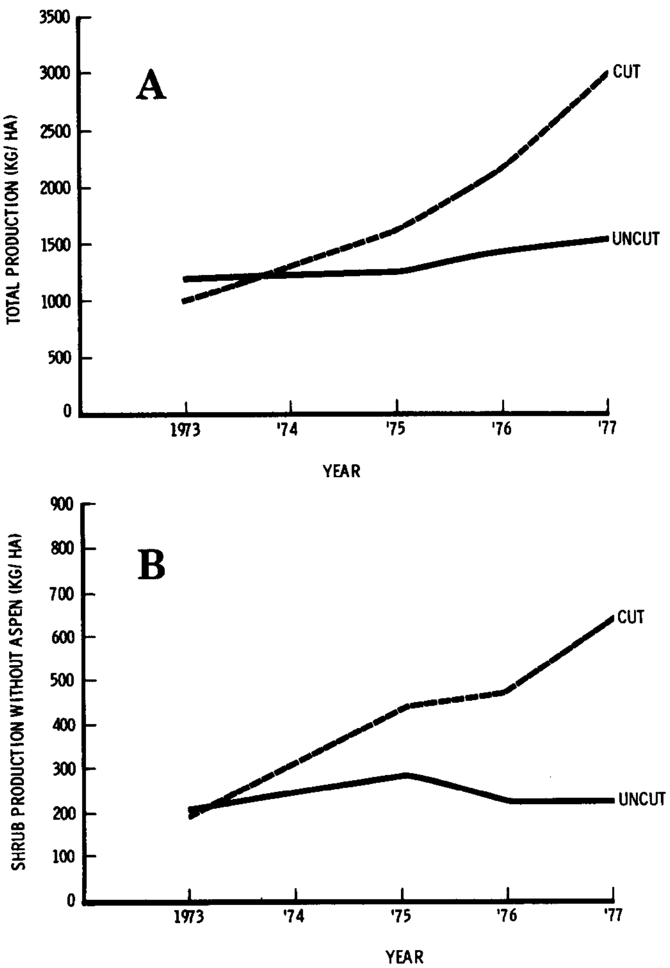
The cutting operation was carried out during the 1974 growing season. All trees over 5.1 cm d.b.h. were cut (approximately 15,000 m³/ha) and all usable boles were removed from the site for firewood. To minimize site disturbances, horses were used to skid the boles and the slash was left in place. (Slash was removed from the macroplots and adjacent border to facilitate sampling.) Data from the 4 cutting units were combined even though the units represented different exposures. This was done because (1) vegetation on the units did not differ greatly, (2) response of the vegetation to cutting was generally similar, and (3) the limited number of paired macroplots did not permit a legitimate statistical analysis of differences between units.

A paired *t*-test was used to evaluate the differences in undergrowth production between the cut and uncut areas. A paired *t*-test using 1973 as the base year was also used to determine the significance of production changes on the uncut areas which are attributable to weather.

Results and Discussion

Undergrowth Production

In 1973, before cutting, total production of undergrowth on the areas to be clearcut and on those to be left as controls did not differ significantly (Table 1). Although production on the uncut control increased slightly over the study period, until it was 28% greater in



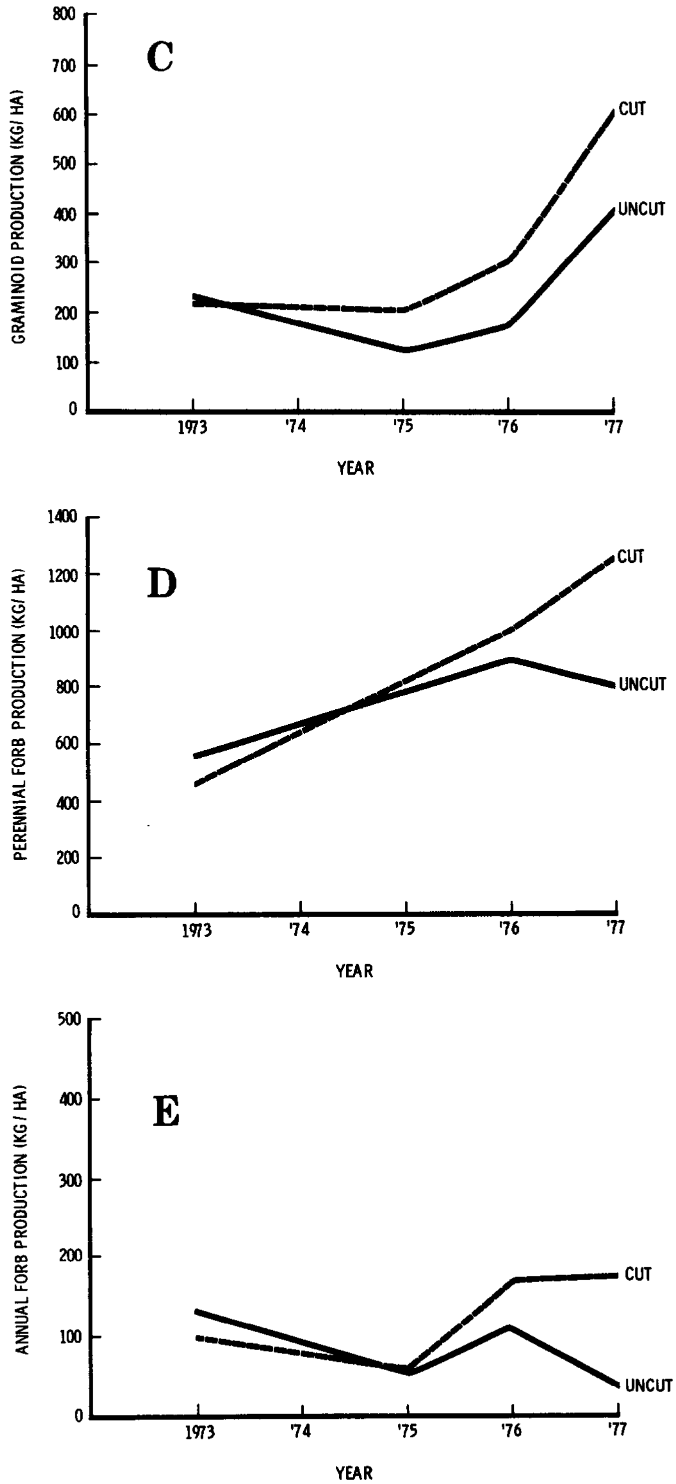


Fig. 2. *Changes in production (dry kg/ha) of undergrowth on clearcut aspen and uncut control areas in 1973 before cutting in 1974, and during the first 3 years following cutting.*

Table 1. Total dry weight production (kg/ha) and standard error on clearcut aspen and on uncut control areas in 1973 before cutting in 1974, and during the first 3 years following cutting.

	1973		1975		1976		1977	
	Cut	Uncut	Cut	Uncut	Cut	Uncut	Cut	Uncut
Total	1013	1199	1625	1267	2175	1431	3002	1539
Standard error	61	86	118	126	154	96	129	86

1977 than in 1973, undergrowth production on the cut areas trebled (Fig. 2A). The small but statistically significant increase in production on the uncut areas was probably the result of natural variations in weather, but this could not be verified. The very great increase in production on the cut areas is probably a combination of the effects of weather and release from competition caused by clearcutting. In each of the 3 years following cutting, production of undergrowth was significantly greater on the cut than on the uncut control. By the third post-cut year, the clearcuts were producing twice as much total shrubs, forbs, and graminoids as the uncut aspen forest.

Perennial forbs contributed considerably more to the total undergrowth production (approximately 50%) both before and after clearcutting than any other vegetation class (Fig. 2). Forb production on the uncut areas varied but increased about one-third over the study period, presumably because of weather differences. Significantly less forbs occurred on the cut areas than on the uncut areas before cutting in 1973. Clearcutting the aspen, however, caused a rapid and progressive increase in production of forbs. By the third post-cut year, forb production had more than doubled on the cut areas, and was more than 50% greater than that on the uncut control (Fig. 2D).

Grasses and sedges comprised about 20% of the original undergrowth production. These graminoids were equally abundant on the cut and uncut areas initially. They increased appreciably during the study period on both treatments (Fig 2C). Although the increase was greatest on the cut areas, differences in production between the cut and the uncut were statistically significant only in 1975 because of the variability in production among macroplots.

Shrubs, excluding aspen reproduction, made up slightly less than 20% of the undergrowth production, and were equally abundant on the cut and uncut areas initially. (Our production values for shrubs consist only of the current growth of twigs, leaves, and fruits). Shrub production did not change appreciably on the control areas during the study period. On the cut areas, however, shrub production doubled the first post-cut year, and by the third year

Table 2. Undergrowth composition (%) on clearcut aspen and uncut control areas in 1973 before cutting in 1974, and in the first 3 years following cutting.

	1973		1975		1976		1977	
Species	Cut	Uncut	Cut	Uncut	Cut	Uncut	Cut	Uncut
Shrubs:								
Populus tremuloides[1]	0.5	0.1	5.1	0.5	10.8	1.1	8.6	2.8
Prunus virginiana	3.7	0.9	10.8	1.7	6.9	2.2	8.8	1.3
Rosa ssp.	-0-	-0-	1.0	1.1	-0-	0.4	0.1	-0-
Sambucus spp.	0.1	0.3	-0-	2.7	-0-	1.0	—	—
Symphoricarpos oreophyllus	15.4	15.8	14.9	16.5	14.7	11.9	12.3	12.8
Total shrubs	19.7	17.1	31.8	22.5	32.4	16.6	29.8	16.9
Graminoids:								
Agropyron trachycaulum	3.6	2.9	3.4	2.1	2.6	3.2	8.4	3.8
Bromus carinatus	11.6	9.3	6.5	4.8	10.5	4.3	9.1	15.7
Carex hoodii	-0-	2.2	0.1	1.2	0.4	3.6	0.1	1.8
Elymus glaucus	4.8	3.9	2.5	1.4	0.5	0.5	2.6	4.7
Poa cusickii	1.8	0.8	0.1	0.2	-0-	0.3	—	—
Total graminoids	21.8	19.1	12.6	9.7	14.0	11.9	20.2	26.0
Perennial forbs:								
Agastache urticifolia	4.9	3.5	5.4	3.6	6.1	9.6	5.3	5.0
Aster engelmannii	2.5	1.3	2.3	1.1	1.1	0.7	3.9	2.7
Chlorocrambe hastatus	—	—	-0-	1.0	0.1	0.4	0.2	1.5
Erigeron spp.	1.0	0.7	1.0	-0-	1.3	-0-	1.6	0.3
Hackelia floribunda	0.9	2.9	0.9	3.8	1.7	1.2	0.3	0.3
Heracleum lanatum	-0-	1.5	1.8	-0-	0.7	0.3	0.4	0.4
Lathyrus leucanthus	3.3	3.9	2.2	3.9	1.7	2.9	2.6	5.1
Mertensia arizonica	0.8	6.6	0.2	4.1	1.1	8.1	0.5	5.1
Osmorhiza chilensis	1.4	0.4	0.5	0.3	-0-	1.5	0.1	-0-
Osmorhiza occidentalis	-0-	1.0	0.3	2.1	0.3	0.7	0.7	0.9
Rudbeckia occidentalis	3.8	0.5	3.6	8.5	6.0	6.1	7.3	7.1
Scrophularia lanceolata	0.1	1.9	4.7	7.6	4.5	2.8	6.0	6.5
Senecio serra	4.3	3.4	10.1	4.7	6.9	9.9	4.2	6.7
Stellaria jamesiana	3.1	2.7	2.7	3.1	1.7	2.6	0.8	0.6
Thalictrum fendleri	0.7	1.3	1.0	0.1	0.1	0.2	0.2	0.7
Valeriana occidentalis	17.9	14.9	11.0	17.0	11.2	12.8	6.7	8.4
Vicia americana	0.8	0.3	2.5	0.8	1.1	2.2	0.7	0.8
Total perennial forbs	45.5	46.8	50.2	61.7	45.6	62.0	41.5	52.1
Annual forbs:								
Chenopodium album	0.4	0.3	0.3	0.2	1.5	1.1	0.5	0.5
Collomia linearis	0.9	0.8	0.2	0.5	1.6	1.8	0.1	0.2
Galium bifolium	2.3	2.8	1.0	0.7	0.3	0.2	-0-	-0-
Nemophila breviflora	3.4	4.3	1.1	1.9	0.2	1.8	—	—
Polygonum douglasii	2.6	2.4	0.7	0.7	4.1	2.7	5.2	1.6
Total annual forbs	9.6	10.6	3.3	4.0	7.7	7.6	5.8	2.3
Other species	3.4	6.4	2.1	2.1	0.3	1.9	2.7	2.7

[1]Only reproduction under 2 m tall and <5.1 cm d.b.h.

was 3 times what it was before cutting (Fig 2B). The increase over the uncut was statistically significant by the third year.

Annuals, consisting exclusively of forbs, initially formed approximately 10% of the undergrowth. Annuals are particularly subject to the vagaries of weather and competitive influences, as evidenced by their erratic production trends over the study period (Fig. 2E). In contrast to the behavior of the other vegetation classes, annuals decreased on the cut as well as on the uncut area the first year after cutting. They then increased significantly on the cut area, so that by the third year production of annuals was fivefold that on the uncut areas. The decrease in annuals immediately following cutting and subsequent increase was unexpected. We assumed that annuals, being opportunistic, would increase appreciably the first year with the immediate reduction in competition and then decrease somewhat as the perennials increased. The initial decrease on both the cut and uncut areas may simply indicate that the weather in 1975 was unfavorable for growth of annuals, and this completely negated the effect of reduced competition. This lack of annual production could be attributed in part to a heavy snowpack during 1974-75, which remained until late June.

Thus, early succession following clearcutting of aspen communities is characterized by a significant increase in the amount of all undergrowth vegetation. This increase is attributed to the reduction in competition from an aspen overstory. As succession proceeds and aspen regains dominance, we expect the upward trend in production of forbs, graminoids, and shrubs to level off and then

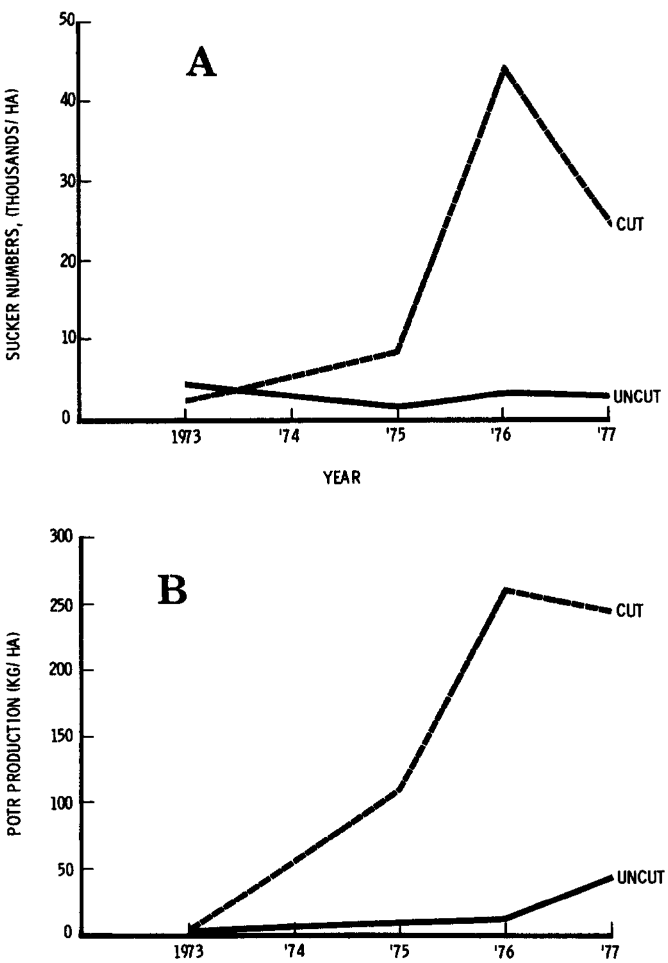


Fig. 3. *Changes in the number (A) and dry weight (B) of aspen suckers on clearcut and uncut control areas in 1973 before cutting in 1974, and during the first 3 years following cutting.*

gradually decrease. Aspen suckers grow rapidly following clearcutting and may begin to suppress production of undergrowth within a relatively few years.

Species Composition

Composition of the undergrowth in these aspen forests was fairly complex. Thirty-two species of plants were sufficiently abundant to individually constitute at least 1% of the undergrowth production in any one year on either of the treatment areas (Table 2).

In general, clearcutting appeared to increase the proportion of shrubs in the undergrowth and decrease the proportion of forbs. In other words, the relative amount of shrubs as a class increased more than the forbs as a class. Even though graminoid production increased on the cut area, its proportion of the total undergrowth did not change appreciably because of cutting.

Forbs contributed most to undergrowth composition in both quantity and in numbers of species. The most abundant forbs were western valerian *(Valeriana occidentalis)*, butterweed groundsel *(Senecio serra)*, nettleleaf giant hyssop *(Agastache urticifolia)*, lanceleaf figwort *(Scrophularia lanceolata)*, and western coneflower *(Rudbeckia occidentalis)*. The relative proportion of different forb species changed from year to year on both the cut and uncut areas (Table 2.) Few species of forbs appeared to be disproportionately favored or harmed by the environmental changes caused by clearcutting. Douglas knotweed *(Polygonum douglasii)*, an annual, appeared to increase proportionately more than any of the other forbs. Butterweed groundsel may have been unusually benefited the first post-cut year, but its increase did not persist. Western valerian was the only forb that appeared to decrease because of clearcutting.

The proportion of graminoids in the undergrowth varied considerably over the study period, from a low of about 10% of the total understory to a high of more than 25% (Table 2). Mountain brome *(Bromus carinatus)*, slender wheatgrass *(Agropyron trachycaulum)*, and blue wildrye *(Elymus glaucus)* were most abundant. Slender wheatgrass was the only species that appeared to be disproportionately affected by clearcutting; its percent composition increased from about 3% of the total undergrowth to 8%.

During the study period, production of shrubs remained fairly constant on the control areas: 16 to 22% of the total undergrowth. Mountain snowberry *(Symphoricarpos oreophyllus)* and common chokeberry *(Prunus virginiana)* were by far the most abundant shrubs. The proportion of mountain snowberry in the community did not appear to be affected by clearcutting. The proportion of common chokecherry, however, appeared to increase on the clearcut areas.

To facilitate understanding the overall divergence of undergrowth composition caused by clearcutting, we computed Sorensen's community coefficient (Mueller-Domboise and Ellenberg 1974) as an index to the similarity of the cut and uncut areas each year. The data used in this comparison were percentage composition of the undergrowth species rather than actual quantities. Aspen overstory was excluded from the analysis. The index thus compares proportions of species irrespective of differences in total undergrowth production. An index value of 1.00 indicates identical matching of species and composition on the compared areas; a value of 0.00 indicates that the areas have no species in common.

The similarity index between combined macroplots on the cut areas and combined macroplots on the uncut areas was 0.78 before clearcutting in 1973. This value suggests reasonably good agreement in the relative amounts of species in the 2 treatment categories. The index dropped to 0.66 the first post-cut year and then increased to 0.70 the second year and to 0.73 the third year. This suggests that the greatest overall change in species composition on the clearcut areas occurred the first year following cutting, and that recovery of the balance between undergrowth species began soon after even though total productivity of undergrowth continued to increase into the third year.

Aspen Suckers

The number of aspen suckers remained fairly constant on the uncut areas throughout the study period, varying from approximately 1,400 to 4,300 per hectare (Fig. 3A). These suckers remained small and contributed little to the total current-year's production of undergrowth (Fig 3B). As expected, clearcutting the aspen overstory stimulated profuse suckering of aspen, particularly the second growing season following cutting. Sucker numbers increased from 2,300 per hectare before cutting, to 8,500 the first post-cut year, and to a maximum of 44,000 the second post-cut year. By the second year, current twig and leaf production of aspen suckers on the cut areas comprised over 10% of the total production of undergrowth. Numbers of suckers dropped the third post-cut year to approximately 25,000 per hectare, but production of twigs and leaves decreased only slightly.

The 20-fold increase in sucker production is similar to what we reported for an aspen clearcut in southern Utah (Mueggler and Bartos 1977). Smith and others (1972) reported 74,000 to 124,000 suckers per hectare after clearcutting aspen in northern Utah, Jones (1975) found 35,000 suckers per hectare on aspen clearcuts in Arizona and in southwestern Colorado 15,000 to 25,000 suckers per hectare was reported by Hittenrauch (1976). Jones (1976) indicated that 50,000 to 75,000 suckers per hectare is not excessive because of the natural thinning that occurs in aspen stands. A mature stand of aspen in this site contains from 700 to 3,600 stems per hectare.

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Relationships between Overstory Structure and Understory Production in the Grand Fir /Myrtle Boxwood Habitat Type of Northcentral Idaho

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Abstract

Relationships between overstory structure and understory current year production on 20 undisturbed sites of the grand fir/myrtle boxwood habitat type were studied in the Clearwater Mountains of northcentral Idaho. Overstory characteristics measured were tree canopy coverage, sum of the tree diameters, basal area, stand height, and stem density. Understory production was divided into four vegetation classes: (1) shrubs, (2) forbs, (3) graminoid and (4) total production. Regression models predicting current year production of each understory vegetation class were developed using all possible combinations of overstory parameters as independent variables. Canopy coverage and sum of the tree diameters were found to be the best indices of understory production. Canopy coverage was most significantly correlated with total understory production and shrub production. Canopy coverage and sum of the tree diameters were the most significantly correlated overstory parameters with forb production. Graminoid production was not significantly correlated to any of the measured overstory parameters. Basal area, tree density, and stand height were not statistically related to the understory production. Further examination of the models is needed to validate these relationships over the range of the grand fir/myrtle boxwood habitat type. The models are not applicable to areas where recent disturbance such as logging, fire, or disease has affected overstory structure.

In forest stands, understory shrub and herb production available to herbivores is highly dependent on the structure of the tree overstory. Several studies have been conducted which relate understory production to overstory structure in forest stands and have proposed models to predict understory production based on tree stand characteristics such as basal area (Clary and Ffolliott 1966, Gaines et al. 1954, Halls and Shuster 1965, McConnell and Smith 1965) and canopy cover (Anderson et al. 1969; Cooper 1960; Ehrenreich and Crosby 1960; Halls and Shuster 1965; Jameson 1967; McConnell and Smith 1965, 1970; Young et al. 1967). The majority of the published accounts of overstory structure-understory production relationships are for forests in the south, southwest, or midwest United States. Little work has been done relating overstory structure to understory production in the Pacific Northwest.

The objective of this was to determine relationships between overstory structure and understory current year production on undisturbed sites of the grand fir/myrtle boxwood *(Abies grandis/ Pachistima myrsinites)* habitat type in the Clearwater Mountains of northcentral Idaho.

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Study Area and Methods

The study area was located in the Clearwater Ranger District, Nezperce National Forest, northcentral Idaho. Twenty study sites were selected to obtain a range overstory canopy coverage, basal area, stand height and stand density. All sites were of the grand fir/myrtle boxwood habitat type as described by Daubenmire and Daubenmire (1968). Overstories varied in maximum age breast height from 65 to 192 years. Site elevations range from 1120-1620 m with aspects representing all cardinal directions and slopes ranging from 0–54%.

Vegetation measurements were made within a 375-m^2 circular macroplot established on each site. Overstory canopy coverage was measured using a spherical densiometer leveled at 1 m above the ground at the center of the macroplots (Lemmon 1956). The densiometer employs a highly polished, convex, chrome mirror to reflect a large overhead area. Diameter at breast height was measured for all conifer trees over 1.4 m and used to calculate basal area in m^2/ha and sum of tree diameters in m/ha. Average height in meters of the combined dominant and codominant crown classes was determined with a clinometer. All trees greater than 1.4 m high were counted and stem density expressed as number of trees per hectare.

The understory vegetation was divided into four above-ground vegetation classes: (1) shrub, (2) forb, (3) graminoid, and (4) total production. Current year growth of these vegetation classes was sampled between August 9 and 17, 1976, the period of near maximum above-ground production for the year. The circular macroplot was bisected perpendicular to the contour of the slope and five, 0.45 m^2 production microplots were systematically located in each half. One microplot in each half of the macroplot was randomly selected for harvesting. The vegetation production of each class in the remaining 4 microplots was estimated as a percentage of the production of their counter-part class in the microplot to be harvested (Mueggler 1976). All herbaceous vegetation in the harvest microplot was then clipped to the upper surface of the litter layer and separated into their respective vegetation classes. Current year growth of shrubs in the harvest microplot was clipped at the previous spring's bud scar. No vegetation above 3 m from the ground was included in the sample. The clippings were air-dried for 3 days, oven-dried for 12 hours at 60° C, and weighed.

Estimation error was assessed by clipping all 10 microplots at 3 of the study sites after estimating production as described above. A regression equation relating estimates to actual production was derived to correct for estimation error prior to calculating the production for each macroplot.

Canopy coverage and rooted frequency data were collected on each site to characterize species composition of the understory. Forty 2 × 5 dm microplots were systematically placed along two 20 m transects passing through the center of the macroplot, one parallel and one perpendicular to the contour of the slope (Daubenmire 1959).

The production and overstory data were plotted and inspected to ascertain appropriate regression models. Relationships between overstory structure (independent variables), and understory production (dependent variables) were analyzed using the general linear model (GLM procedure), stepwise regression maximum R^2 improvement (STEPWISE procedure), and all possible regressions (RSQUARE procedure) of the Statistical Analysis System (SAS) (Helwig and Council 1979). Two general linear models were considered appropriate and tested for significance:

(1) $Y = a + bX$
(2) $Y = a + bX^{-1}$
where Y= understory production
X = overstory variables.

The best significant ($\alpha \leq .01$) single variable model for each dependent variable was selected.

Multiple independent variable models were also explored. The 3 multiple independent variable models tested were:

(3) $Y = a+b_1X_1 + b_2X_2 ... b_nX_n$
(4) $Y = a+b_1X_1^{-1}+b_2X_2^{-1}...b_nX_n^{-1}$
(5) all possible combinations of (3) and (4) where X_i could be used only once in the equation either as b_iX_i or $b_iX_i^{-1}$.

If the multiple independent variable model yielded a higher coefficient of determination (R^2), then an F-test was used to determine if the multiple variable model R^2 value was significantly ($\alpha \leq .05$) greater than the R^2 of the single variable model.

Results

The overstory on all study sites was dominated by grand fir. However 6 additional subordinate tree species were present in various proportions among the stands (Table 1). Fifteen of the 20 sites had overstory coverage greater than 75% (Table 2). Overstory coverages of less than 50% on undisturbed sites in the Clearwater Mountains were uncommon. Coverage of less than 50% was normally the result of recent disturbances such as logging, fire or disease. Disturbed areas were not sampled since the degree of disturbance can affect plant composition and production making comparisons difficult. A total of 136 vascular plant species were encountered among all 20 study sites. Constancy, canopy coverage, and rooted frequency for selected species sampled at the study sites are shown in Table 3.

Total Production

The relationship between overstory canopy coverage and total production was found to be highly significant ($R^2 = 0.76$) (Table 4, Fig. 1). In addition, sum of the tree diameters and basal area were also significantly related to total production as single variables with R^2 values of 0.54 and 0.37, respectively (Table 4).

None of the multiple independent variable models accounted for a significantly greater portion of the variability in total understory production than the single variable models.

Shrub Production

Three overstory characteristics were significant in predicting shrub production. Canopy coverage, as a single independent variable, had the highest correlation with shrub production (Table 4, Fig. 2).

Other overstory structures significantly correlated with shrub production were sum of the tree diameters and basal area with R^2 values of 0.67 and 0.34 respectively (Table 4).

None of the multiple variable models accounted for significantly greater portions of variability than the single variable model.

Table 2. Mean ($\bar{x}$), standard deviation (s) and range of the overstory and understory variables studied in the grand fir/myrtle boxwood habitat type in the Clearwater Mountains of Idaho.

Variable	$\bar{x}$	s	Range
Overstory			
Sum of the diameters (m/ha)	147.5	46.5	59–214
Canopy coverage (%)	82.4	14.5	50–96
Stand density (trees/ha)	1406.0	1377.6	320–3040
Basal area (m^2/ha)	34.0	14.2	14–67
Stand height (m)	27.2	7.2	11–34
Understory			
Total production (kg/h)[1]	370.0	174.4	153–807
Shrub production (kg/h)[1]	128.3	140.5	3–511
Forb production (kg/h)[1]	195.7	57.5	118–292
Graminoid production (kg/h)[1]	46.0	49.4	0–164

[1]Dry weight.

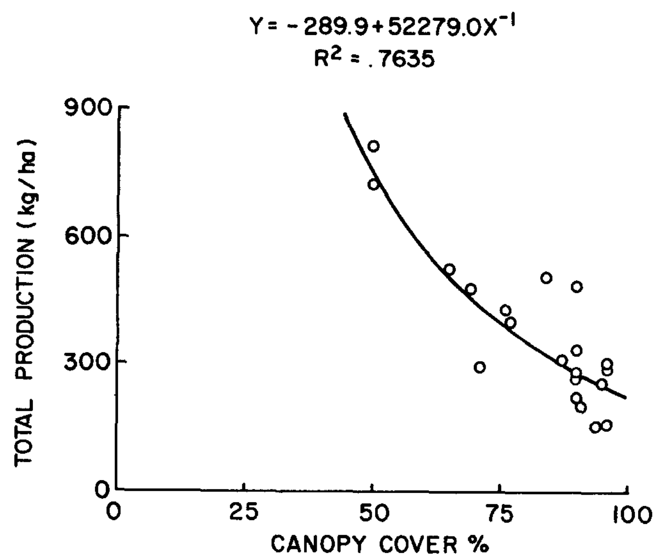

Fig. 1. *The relationship between total production (dry weight) and overstory canopy coverage in the grand fir/myrtle boxwood habitat type of the Clearwater Mountains of Idaho.*

Table 1. Mean ($\bar{x}$) and standard deviation (s) for three overstory structural features of tree species encountered in stands of grand fir/myrtle boxwood habitat type in the Clearwater Mountains of Idaho.

		Sum of the diameters (m/ha)		Basal area (m/ha)		Stand density (trees/ha)	
Species[1]	Common name	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Abies grandis	grand fir	112.2	53.7	24.8	18.6	849.4	685.6
Larix occidentalis	mountain larch	3.4	9.1	1.3	3.5	12.0	36.2
Picea engelmanii	engelmann spruce	10.0	23.7	3.2	8.7	37.8	76.1
Pinus contorta	lodgepole pine	.3	1.1	.1	.2	1.4	6.0
Pinus ponderosa	ponderosa pine	3.8	11.4	2.0	6.3	9.4	21.7
Pseudotsuga menziesii	Douglas fir	17.0	41.8	5.5	14.6	87.8	131.2
Taxis brevifolia	pacific yew	1.0	4.3	.7	2.9	8.0	35.8

[1]Nomenclature follows Hitchcock and Cronquist (1973).

Table 3. Constancy, canopy coverage, and rooted frequency for selected species encountered in stands of the grand fir/myrtle boxwood habitat type in the Clearwater Mountains of Idaho.

Species [1,2]	Common name	Constancy (%)	Canopy coverage[3] (%)	Rooted frquency[3] (%)
			$\bar{x} \pm s_{\bar{x}}$	
Understory trees				
Abies grandis	grand fir	85	9 ± 2	15 ± 3
Pseudotsuga menziesii	Douglas fir	50	2 ± 1	4 ± 1
Shrubs				
Acer glabrum	rocky mountain maple	70	7 ± 2	6 ± 1
Amelanchier alnifolia	western serviceberry	75	4 ± 1	5 ± 1
Chimaphila menziesii	little prince's pine	50	2 ± T[4]	6 ± 1
Chimaphila umbellata	prince's pine	60	2 ± T	16 ± 4
Linnaea borealis	twinflower	85	10 ± 2	50 ± 7
Lonicera ciliosa	trumpet honeysuckle	60	4 ± 1	12 ± 4
Lonicera utahensis	Utah honeysuckle	90	3 ± T	7 ± 1
Pyrola secunda	sidebells pyrola	85	1 ± T	8 ± 2
Ribes lacustre	prickly current	50	7 ± 5	9 ± 4
Ribes viscosissimum	sticky current	45	3 ± 2	6 ± 2
Rosa gymnocarpa	baldhip rose	100	6 ± 2	8 ± 2
Rubus parviflorus	thimbleberry	85	4 ± 2	6 ± 2
Symphoricarpos albus	common snowberry	85	15 ± 6	22 ± 8
Vaccinium membranaceum	big huckleberry	70	16 ± 6	23 ± 6
Xerophyllum tenax	beargrass	75	21 ± 5	18 ± 4
Perennial graminoids				
Bromus vulgaris	columbia brome	90	7 ± 1	25 ± 4
Carex rossii	ross sedge	85	6 ± 1	18 ± 4
Festuca occidentalis	western fescue	60	2 ± T	8 ± 2
Perennial forbs				
Adenocaulon bicolor	trail-plant	90	6 ± 2	25 ± 6
Anemone piperi	piper's anemone	95	4 ± 1	38 ± 4
Arenaria macrophylla	bigleaf sandwort	75	4 ± 1	23 ± 4
Clintonia uniflora	beadlily	100	5 ± 1	23 ± 4
Coptis occidentalis	Idaho goldthread	100	12 ± 2	60 ± 6
Fragaria vesca	woods strawberry	95	3 ± 1	22 ± 4
Galium triflorum	sweetscented bedstraw	85	3 ± 1	21 ± 4
Goodyera oblongifolia	western rattlesnake plantain	75	2 ± 1	10 ± 3
Hieracium albiflorum	white-flowered hawkweed	80	2 ± T	19 ± 3
Mitella stauropetala	side-flowered miterwort	80	2 ± T	15 ± 4
Osmorhiza chilensis	mountain sweetroot	90	2 ± T	14 ± 2
Pedicularis racemosa	leafy lousewort	75	2 ± 1	15 ± 3
Smilacina stellata	starry solomon-plume	95	4 ± 1	21 ± 3
Thalictrum occidentalis	western meadowrue	80	7 ± 1	20 ± 4
Tiarella trifoliata	foamflower	70	3 ± 1	16 ± 4
Trillium ovatum	western trillium	80	2 ± T	10 ± 2
Viola orbiculata	darkwoods violet	75	4 ± 1	42 ± 6

[1]Nomenclature follows Hitchcock and Cronquist (1973).
[2]Only those species which have constancies of 50% or greater are shown.
[3]Values represent averages based only on those macroplots in which the species was found.
[4]T = less than 0.5% coverage.

Forb Production

Overstory canopy coverage was the only significant, single variable related to forb production ($R^2 = 0.32$) (Table 4, Fig. 3). A multiple independent variable model combining overstory canopy coverage and sume of the tree diameters accounted for a significantly greater ($\alpha \leq 0.05$) variation than the single variable model alone ($R^2 = 0.47$) (Table 4).

Graminoid Production

The graminoid production was not significantly correlated with any of the measured overstory structures in both single and multiple independent variable models.

Discussion

Overstory canopy coverage, as measured with a spherical densiometer, was the best single independent variable for predicting the production of all understory vegetation classes except graminoids. Reifsnyder and Lull (1965) demonstrated a high correlation between overstory canopy coverage, as measured with a spherical densiometer, and light intensity and net radiation at the forest floor. Vezina and Pech (1964) and Reifsnyder and Lull (1965) have shown that measured light interception can be 60 to 100% in the range of canopy coverages examined in our study depending upon needle and branch density in the canopy of the stand.

The spherical densiometer integrates several structural features of the overstory into a single measurement of canopy coverage. Because of the convex curvature of the mirror, the view of the overstory canopy is like that of a wide angle lens with an infinite depth of field. At the center of the mirror, crown width is the predominant structural tree feature observed. Near the periphery of the mirror within the estimation grid, crown length, vertical bole area, and bole density become increasingly important structural features contributing to canopy coverage. The spherical densiometer accounts for a large portion of the total overstory which can inhibit light penetration to the understory, especially light penetrating the canopy from low angles.

Sum of tree diameters was found to be a good predictor of shrub

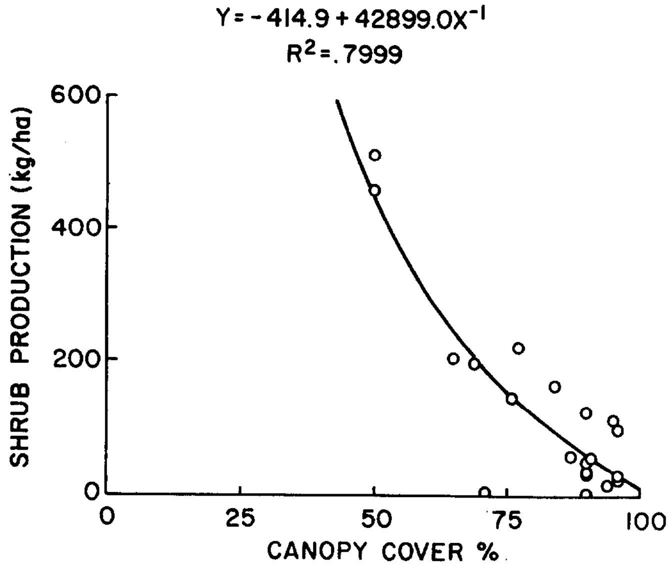

Fig. 2. *The relationship between shrub production (dry weight) and overstory canopy coverage in the grand fir/myrtle boxwood habitat type of the Clearwater Mountains of Idaho.*

and total understory production. This variable is easily measured and calculated and is readily available from timber survey data. This parameter has been shown to be closely related to the length and basal width of live tree crown (Arnold 1948), and also a good index of the transmission of solar radiation (Miller 1959, Reifsnyder and Lull 1965, Wellner 1948, Vezina and Pech 1964).

In contrast to sum of tree diameters, basal area was a poor predictor of all understory production classes. Basal area gives little weight to small bole diameter trees which can provide a substantial amount of light intercepting crown (Miller 1959). Basal area will generally increase with stand age and will not consistently reflect changes in the canopy due to the establishment or death of small bole diameter trees.

It is important to realize that sum of tree diameters and basal area do not completely represent the mass and distribution of the canopy that intercepts light in a forest stand. Assmann (1970) concluded that stem diameter and area cannot be considered at all times as a close correlate to canopy structure. In a completely

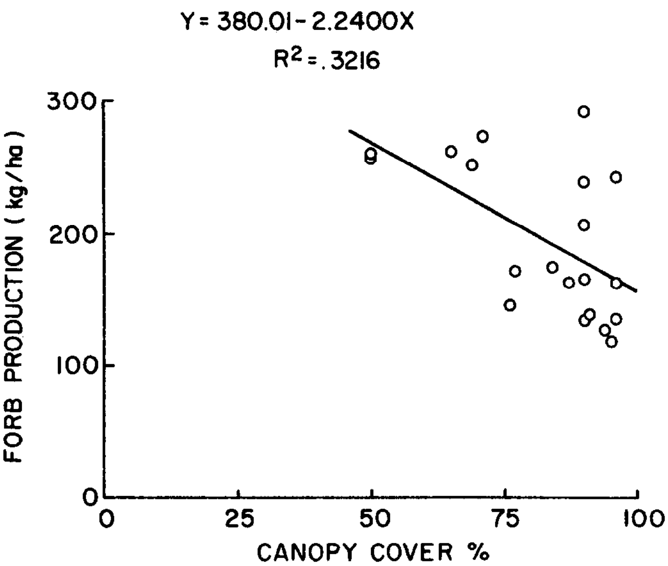

Fig. 3. *The relationship between forb production (dry weight) and overstory canopy coverage in the grand fir/myrtle boxwood habitat type of the Clearwater Mountains of Idaho.*

Table 4. Coefficients of determination (R^2) and regression equations for estimating production (Y) in kg/ha of understory vegetation using sum of the diameters of tree (S) in m/ha, overstory tree canopy coverage (C) in % and basal area (B) in m²/ha as independent variables for the grand fir/myrtle boxwood habitat type in the Clearwater Mountains of Idaho. All models are significant at $\alpha \leq 0.01$.

Vegetation class	Independent variables		Model	R^2
Total Production				
	C		$Y = -289.9 + 52279.0\ C^{-1}$	.7635
	S		$Y = 81.0 + 39048.7\ S^{-1}$	.5362
Shrubs				
	C		$Y = -414.9 + 42899.0\ C^{-1}$	.7999
	S		$Y = -131.6 = 34891.4\ S^{-1}$	.6661
	B		$Y = 65.3 + 5129.9\ B^{-1}$	.3385
Forbs				
	C	S	$Y = 388.5 - 3.6\ C + 0.7\ S$	.4738
	C		$Y = 380.0 - 2.2\ C$	.3216

closed stand where lateral growth of the crown is limited, stem diameters will continue to increase. When such a stand is thinned to substantially reduce canopy coverage, crown size increases at a faster rate than the stem diameters. Bole measurements serve only as estimations of canopy structure which actually intercepts solar radiation, where spherical densiometer measurements will more accurately reveal changes in the canopy.

Stand height as a single independent variable was least correlated with production in all vegetation classes. When stand height was entered into a two variable model with canopy coverage or the inverse of canopy coverage, significantly correlated models were derived with coefficients of determination greater than models containing canopy coverage alone. Yet *F*-tests demonstrated that no significant additional variance was explained by the addition of stand height.

Stem density was not significantly correlated with any of the vegetation classes in single or multiple independent variable regression models. This could be attributed to the fact that as the canopy develops the stem density may remain constant and thus not reflect the decrease in light penetration to the understory.

Graminoid production was the only understory vegetation class not correlated with any of the measured overstory structural features. Thirteen species of graminoids were encountered among all the stands sampled; however, only 3 contributed significantly to understory production. These were, in decending order of abundance, columbia brome, ross sedge, and western fescue (Table 3). Graminoid production varied from 0–57 kg/ha under both high and low canopy coverage. Daubenmire and Daubenmire (1968) showed similar variation in graminoid abundance among climax stands of the grand fir/myrtle boxwood habitat type of northern Idaho and eastern Washington. The results of Daubenmire (1953) and Moir (1966) suggest that the soil nutrient status may be a major factor determining the growth response of graminoids under shaded conditions.

Conclusions

Our results indicate that understory production is closely correlated with overstory canopy coverage and sum of the tree diameters on undisturbed sites of the grand fir/myrtle boxwood habitat type. Since both overstory characteristics are good indices of solar radiation transmission through tree canopies to the understory, the data indicate that solar radiation is a major limiting factor of understory production in this study area. Both overstory characteristics are easily measured, and in the case of tree diameters, readily available from timber survey data. Use of such parameters would greatly facilitate estimation of understory production for range inventory purposes. Further examination of the models is needed to verify these relationships over the range of the grand fir/myrtle boxweed habitat type.

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Soil Water Depletion by Yucca

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Abstract

Encroachment of *Yucca* sp. onto newly cleared rangelands often presents a larger problem than caused by the noxious species initially controlled. Densities of yucca often approach or exceed 5000 plants/ha, potentially depleting soil water and reducing forage production. An evaluation of soil water (0 to 60 cm depths) during April 1971 through August 1975 revealed the yucca-infested rangeland had a significantly lower water content than yucca-free rangeland. Herbage production was also significantly reduced by yucca during years with a higher soil water content. Partially thinning yucca densities did not increase soil water content. Soil water storage was increased only when all yucca was removed.

Restoration and conservation of native rangelands in the Southwest are among the most important problems confronting the ranching industry today. Control of noxious brush and some weeds ranks as a high priority among ranchers in the Southwest.

Approximately 310 million ha of rangeland in the southwestern U.S. (Texas, New Mexico, and Arizona) are infested with noxious brush (U.S. Dep. Agr. Soil Conserv. Serv. 1978) including plants such as mesquite (*Prosopis* sp.), "cedar" (*Juniper* sp.), and oak (*Quercus* sp.). Active programs have been underway for many years to control noxious brush. Following removal of some major noxious species, often secondary species that are equally as noxious invade the area. Following control of honey mesquite *(P. glandulosa),* ash and redberry juniper (*J. ashii* and *J. pinchotii,* respectively), yucca (*Yucca* sp.) often invade the cleared areas. It has been estimated that approximately 4.9 million ha in Texas alone (predominately in the Panhandle area) are infested with *Y. glauca* (Robison 1968).

Chemical control of *Y. glauca* in the Panhandle of Texas increased desirable herbage production approximately 37% over untreated areas (Robison 1968). Much of the increase occurred within the dead yucca clumps. Significant production of forage species follows control of Utah juniper *(Juniperus osteospermus)* (Clary 1971) and mixed brush in South Texas (Dodd and Holtz 1975, Gonzales and Dodd 1979, Durham et al. 1975, and Scifres and Polk 1975). Control of velvet mesquite *(P. velutina)* increased perennial grass production 52% over a period of 10 years in southern Arizona (Cable and Martin 1975). Similarly, control of honey mesquite increased herbage production over a 5-year period in the Rolling Plains of Texas (Dahl et al. 1978).

Presumably, increases in forge production result from increased soil water following control of undesirable species. Herbage yields are highly correlated to soil water content, particularly to preseason stored water (Dahl 1963; Gonzales and Dodd 1979).

This study was initiated to evaluate the influence of yucca (*Y. glauca, Y. constricta,* and their hybrids) on soil water depletion and herbage response to different densities of yucca.

Study Area and Experimental Procedures

This study was conducted from April 1971 through August 1975 on an Edward's Plateau outcropping within the Rolling Plains of Texas, near Sweetwater. Physiographically, the area is located on the Callahan Divide, in Nolan County, which forms a boundary between the Colorado and Brazos River basins. The soils of the area are characterized by a Berda fine sandy loam on a Mixland range site.

Climate of the area is intermediate between the subhumid climate of east Texas and the semiarid climate of the Southwest. The average annual precipitation is 61 cm, most of which occurs in the form of rain. Most (76%) of the rainfall occurs April through October as localized, short duration thunderstorms of high intensities.

Herbaceous vegetation of the study area consisted primarily of sideoats grama *(Bouteloua curtipendula),* hairy grama *(B. hirsuta),* blue grama *(B. gracilis),* silver bluestem *(Bothriochloa saccharoides),* perennial threeawns *(Aristida purpurea, A. wrightii, A. longiseta, A. glauca,* and *A. oligantha),* sand dropseed *(Sporobolus cryptandrus),* buffalograss *(Buchloe dactyloides),* hooded windmill *(Chloris cuculata),* Reverchon's panic *(Setaria reverchonii),* and Texas croton *(Croton texensis).* Following control of ash and redberry juniper, yucca invaded the area and became the dominant noxious species. The density of yucca on the study area was approximately 5000 plants/ha (determined by counting the number of individual plants/0.1 ha).

The study was designed as randomized complete blocks with 3 treatments and 3 blocks. All blocks were 30 × 30 m and separated by 4.6 m buffers. The treatments consisted of no yucca, approximately 2500 yucca plants/ha and approximately 5000 yucca plants/ha.

Originally, yucca was hand-grubbed from the treatments containing no yucca and 2500 plants/ha. Yucca densities were maintained for the duration of the study by hand-grubbing periodically. All woody plants were similarly removed from every plot by hand-grubbing.

Soil water content was measured weekly June through August and monthly from September through May each year. Soil cores were collected in 15-cm increments to a depth of 60-cm from which soil water content was determined gravimetrically. Soil samples were oven-dried at 100° C for a minimum of 24 hr. The soil water content (%) represented an average from 4 random soil cores/treatment/block/sampling date. Precipitation was recorded on the study area.

Herbage yields were measured during August of 1972, 1973, and 1974. Herbaceous plants were harvested by species and yields represented an average obtained from 5 random 0.45 m^2 quadrats/treatment/block.

Results and Discussion

Evidence of the effect of yucca on soil water depletion was observed from April 1971 through August 1975. Soil water content was significantly higher where yucca had been removed compared to the treatments that consisted of either 2500 or 5000 plants/ha (Fig. 1). The soil water content was significantly higher (P=0.05) in the areas consisting of no yucca vs. areas consisting of either 2500 or 5000 plants/ha. The average soil water content of the treatment in which yucca had been removed ranged from 5.4% in July to 15.4% in October. However, the average soil water content ranged from a low of 4.8% and 4.7% in July to a high of 14.3% and 14.0% in October in treatments consisting of 2500 and 5000 plants/ha, respectively. Seemingly yucca must be completely controlled or removed to significantly increase soil water storage. Partial elimination or thinning yucca is of little or no significance in soil water conservation. Similar results have been found in mesquite (B.E. Dahl, unpublished data; Thomas 1976) and broom snakeweed (Ueckert 1979).

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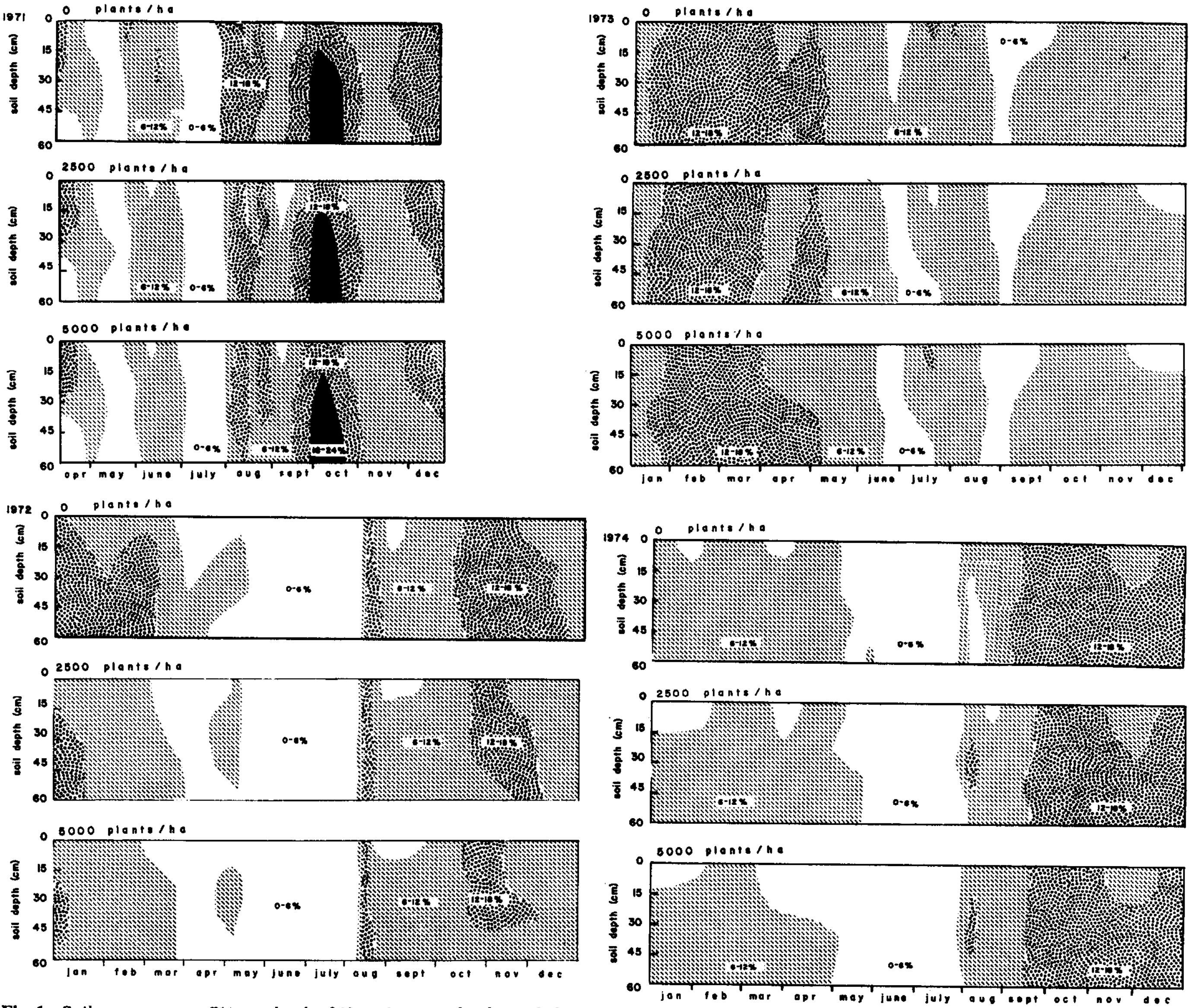
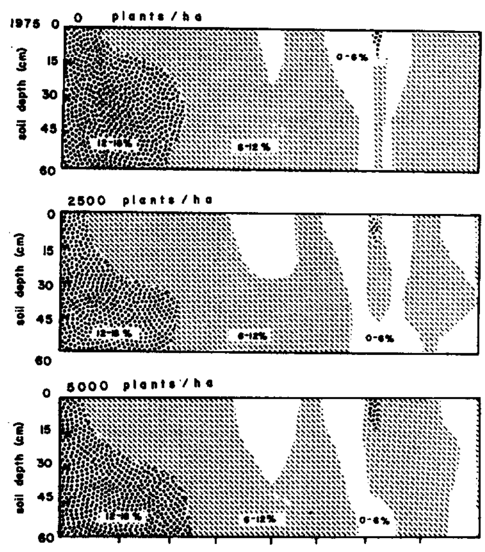


Fig. 1. *Soil water content (%) to a depth of 60 cm (average depth to caliche) as influenced by different densities of yucca from April, 1971 through August, 1975.*

Soil water content exhibited seasonal trends since most of the precipitation was received during August and September (Fig. 2). Soil water content remained relatively high throughout most of the fall and winter. During the spring, soil water content was consistently lower, which should be expected because of the amount of plant growth during this period of the year. As the rate of plant growth slowed and the plants entered quiescence during the latter part of the summer, soil water content increased in relation to the amount of precipitation.

The growth habits of yucca also affected the amount of water retained in the soil. Root excavations revealed that yucca commonly develops underground stems 7.5 cm in diameter at depths of 45 to 60 cm, at which depth the stems branch and grow laterally either parallel with or ascending to the soil's surface. Buds form on the underground stems and ultimately emerge as new plants. The underground stems have many roots varying from 2 to 4 mm in diameter and may extend laterally for several meters. Thus, yucca has the capacity to deplete significant amounts of soil water. The pattern of soil water depletion indicates that the depth of most active root absorption occurs between 45 and 60 cm (especially on shallow soils).

Herbage production was related to yucca control and soil water depletion. Complete removal of yucca significantly increased grass



yield during 1973 (Table 1) while forb production was concomitantly reduced. The significant increase in grass production during 1973 seemed to be related to the amount of precipitation received during the fall of 1972 (Fig. 2). Although production of warm-

Table 1. Grass and forb production (kg/ha) in 1972, 1973, and 1974 as influenced by 3 densities of yucca (0, 2500, 5000 plants/ha) growing on shallow soils near Sweetwater, Texas.

No. yucca plants/ha	Year 1972	1973	1974	$\bar{x}$[2]
	Grass production			
	A[1]	B	A	
0	904 a	1937 b	687 a	1176
	A	A	A	
2500	880 a	1512 a	803 a	1065
	A	A	A	
5000	927 a	1584 a	850 a	1120
	Forb production			
	A	B	B	
0	450 x	215 x	229 x	298
	A	A	a	
2500	365 x	284 x	150 x	266
	A	A	A	
5000	429 x	268 x	104 x	267

[1]Values in a row with similar capital letter superscripts are not significantly different (P=0.05). Values in a column followed by similar lower case letters are not significantly different (P=0.05). No statistical comparisons were made between grass and forb production.

[2]Not included in a statistical analyses.

season perennials such as silver bluestems, three-awns, and sand dropseed was increased, Texas wintergrass *(Stipa leucotricha)* accounted for a substantial amount of the production in 1973. Similar results that indicate herbage yield of native plants is more closely related to the amount of precipitation received during the fall preceding the growth season in which growth is expressed than to the amount received during the growing season have been reported by Dahl (1963). Interestingly, even during a "wet year" there apparently is not sufficient soil water to support dense stands of yucca (5000 plants/ha) and an increase in grass production. During "wet years" grass production is reduced apparently because of competition from yucca.

Summary and Conclusions

Many acres of mesquite and juniper infested rangeland are controlled annually, only to be invaded by other noxious species such as yucca. Stands of yucca often become very dense (5000 plants/ha) and compete with more desirable species for water, nutrients, and even space.

Complete removal or control of yucca significantly increases amounts of soil water storage in the rooting zone of more desirable herbaceous plants. Partial control or thinning has little effect on increasing soil water content. Similarly, complete control of yucca allows herbage yield to increase when adequate precipitation occurs; whereas, no substantial yields occur if yucca is present in moderate to dense stands, even if precipitation is adequate. Therefore, if one decides to control yucca to increase soil water content and concomitant herbage yield, one must strive for complete control.

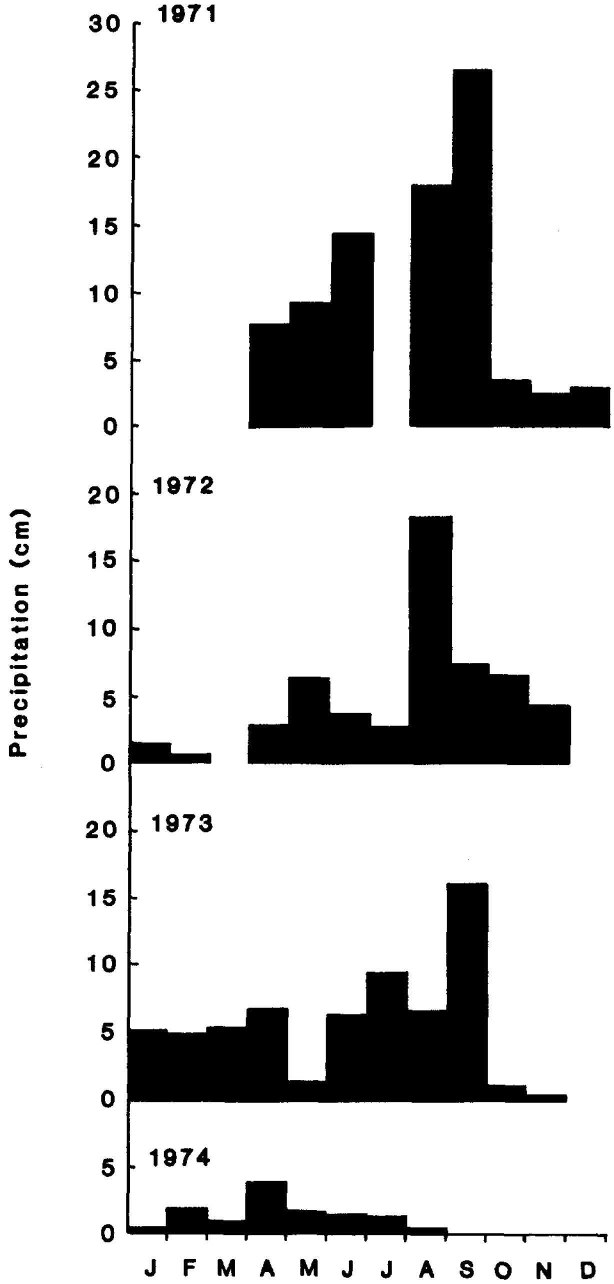


Fig. 2. *Monthly precipitation (April, 1971 through August, 1975) that influenced the soil water content and herbage yield on a Mixland range site near Sweetwater Texas.*

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Optimum Allocation in Multivariate Double Sampling for Biomass Estimation

JAVED AHMED AND CHARLES D. BONHAM

Double sampling or two-phase sampling involves sampling of any population in 2 phases. The first phase yields data on any desired factor by direct measurements as well as by some indirect method. In the second phase, data are collected by the indirect method only.

The estimated variance in double sampling with regression and ratio estimators are described in detail by Cochran (1963). The first sample is a simple random sample of size n′. The second sample of size n is a random subsample from the first sample, but may be drawn independently if this is more convenient. The first step is to set up the estimate and to determine its variance. The auxiliary variate (x_i) is used to make a regression estimate of y. It is assumed that the population is finite but very large and that the relation between y_i and x_i is linear. In the first (large) sample (size n′), only x_i is measured. In the second (small) sample (size n), both x_i and y_i are measured.

One of the major problems in double sampling is determining the number of samples required in each phase to give the desired accuracy for the maximum economy. The efficiency of double sampling depends on two things: (1) the precision of the mathematical relationship, and (2) the cost of direct measurements compared to indirect estimates.

If too many direct samples are taken, the cost of sampling becomes unnecessarily high, while the use of too few direct samples results in an unreliable mathematical relationship. Thus, it is desirable to estimate the size of the two samples; the large sample (n′) and the small sample (n). In its application to estimating crop biomass, the first phase of double sampling involves estimation of the plant biomass ocularly or by capacitance meter. In the second phase, the plant biomass is estimated as in the first phase followed by clipping and weighing of the plants. For a detailed discussion on the statistical aspects of the double sampling, the reader is referred to Schumacher and Chapman (1948), Hansen et al. (1953), National Research Council (1962), and Cochran (1963).

With a single factor under study and for a given sampling procedure, optimum allocation of resources to direct and indirect methods of estimation is well defined. However, a simple procedure for optimum allocation in multivariate double sampling is not available. A technique is described which enables the investigator to find optimum allocation in multivariate double sampling which minimizes cost or variance and also gives achievable variances of the estimated means.

For sampling involving a single independent variable, the procedure for optimum allocation in double sampling is reviewed. According to Cochran (1963), the cost of double sampling is

$$C = nc_n + n'c_n' \quad (1)$$

where

C = total cost of double sampling
c_n = cost of obtaining one direct sample
c_n' = cost of obtaining one indirect sample
n = number of direct samples
n′ = number of indirect samples.

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For a fixed cost C, optimum allocation (for minimum variance is obtained when

$$\frac{n'}{n} = \frac{\sqrt{V_n' c_n}}{\sqrt{V_n c_n'}} \quad (2)$$

$$= \sqrt{\frac{c_n \rho^2}{c_n' (1 - \rho^2)}} \quad (3)$$

where

$$V_n = (S_y^2)(1 - \rho^2) \quad (4)$$

$$V_n' = \rho^2 S_y^2, \quad (5)$$

and

ρ = coefficient of correlation between y_i and x_i in sample n
S_y = standard deviation of y_i.

Equations (1) and (2) or (3) determine n and n′. The techniques for allocation in double sampling described by Wilm et al. (1944) and Schumacher and Chapman (1948) are essentially the same as the one described by Cochran (1963), and are, therefore, not given here.

In our study of optimum allocation for multivariate double sampling, the variance of the mean desired for the estimates of each variate was specified, and the optimum allocation was the one which achieved this at a minimum cost. Therefore, the basic approach was to attain specified levels of precision at the minimum cost. First, the variance of the regression and ratio etimator in double sampling is given and then the allocation problem is formulated and its solution described.

Estimated Variances in Double Sampling

The estimate of $\bar{y}$ is

$$\bar{y}_{1r} = \bar{y} + b(\bar{x}' - \bar{x}) \quad (6)$$

where $\bar{x}'$ and $\bar{x}$ are the means of x_i in the indirect and direct samples, respectively, and b is the least squares regression coefficient of y_i on x_i, computed from the direct sample.

The variance of $\bar{y}_{1r}$, the regression estimate in double sampling, is

$$V(\bar{y}_{1r}) = \frac{V_n}{n} + \frac{V_n'}{n'}, \quad (7)$$

and a sample estimate of $V(\bar{y}_{1r})$ is

$$\hat{V}_{(y_{1r})} = \frac{s^2_{y\,.\,x}}{n} + \frac{s^2_y - s^2_{y\,.\,x}}{n'}. \quad (8)$$

Optimum Allocation

The cost of double sampling is given in equation (1). With k variates, let V^o_j be the specified variance tolerance for the mean of the j^{th} variate. The precision specifications become

$$V(\bar{y}_j) \leq V^o_j \,. \quad (9)$$

From the approximate expression of variance in equation (7) and from (9), it foll~ws that

$$\frac{Vn_j}{n} + \frac{Vn'_j}{n'} \leq V^o_j, \quad (10)$$

and the allocation problem with k variates becomes

$$\text{minimize } C = nc_n + n'c_n' , \tag{11}$$

subject to

$$\frac{V_{n_j}}{n} + \frac{V_{n'_j}}{n'} \leq V^{\circ}_j \tag{12}$$

$$(j = a, \ldots, k)$$

$$n' > n > 0.$$

The overhead costs have been neglected because these do not enter into the optimization problems (Kokan 1963).

By obtaining a solution to the above plan, we actually obtain the solution to a series of plans. Let C° be the sampling cost

$$C^{\circ} = nc_n + n'c_n' , \tag{13}$$

which satisfies

$$\frac{V_{n_j}}{n} + \frac{V_{n'_j}}{n'} \leq V^{\circ}_j , \tag{14}$$

then the fixed cost (C') sample

$$C' = \frac{C^{\circ}}{r} \tag{15}$$

is

$$\frac{n}{r} \text{ and } \frac{n'}{r}, \; r > 0, \tag{16}$$

which satisfies

$$V(\bar{y}_j) \leq rV^{\circ}_j \, . \tag{17}$$

Choice of Precision Specifications

No definite answer can be given to the question, "what is a desirable level of precision?" The desired precision will depend on the purpose at hand. The quantities V_n and V_n' on the left-hand side of the inequalities can be estimated from a preliminary sample in which y_i is measured and x_i is estimated for each variate. The V°_j, or the righthand side of the inequalities are specified:

1. from the past experience or from values reported in the literature, or
2. by specifying coefficients of variation for $\bar{y}$ of each variate

$$CV(\bar{y}_j) = \frac{SE(\bar{y}_j)}{\bar{y}_j} \text{, or} \tag{17}$$

3. by specifying a bound (B) on the error of the estimate

$$B = 2SE, \tag{18}$$

which is equivalent to

$$V(\bar{y}_j) = \frac{B^2}{4} \, . \tag{19}$$

Solution of the Allocation Problem

The purpose of optimization is to find the best possible solution among the many potential combinations of sampling ratios for a given problem in terms of effectiveness or performance criterion. The usual analytical approach for optimization of nonlinear programming problems is to use the calculus and/or Lagrange multipliers. However, the geometric programming approach of Duffin et al. (1967), developed for solving algebraic nonlinear programming problems, was used to obtain solutions to the multivariate double sampling problem. A programming algorithm using the above analytical techniques has been described in detail by Ahmed and Bonham (1980).

Test data for this allocation problem were collected at the Central Plains Experimental Range, administered by the Science and Education Administration-Agricultural Research of the U.S. Department of Agriculture, near Nunn, Colo. Statistical summaries of the double sampling data are given in Table 1.

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                    COLORADO STATE UNIVERSITY
                    RANGE SCIENCE DEPARTMENT

************* PROGRAM FOR OPTIMUM ALLOCATION IN DOUBLE SAMPLING *************


HOW MANY CONSTRAINTS
? 6
COST FUNCTION
? 5 .5
INPUT CONSTRAINT COEFFICIENTS AND RIGHT-HANDSIDE
(SEPARATED BY A COMMA OR A SPACE)
CONSTRAINT 1:
? 5.5 106.8 .24
CONSTRAINT 2:
? 36.8 182.2 3.14
CONSTRAINT 3:
? 5.8 31.8 .28
CONSTRAINT 4:
? .9 5.9 .04
CONSTRAINT 5:
? 3.3 15.2 .056
CONSTRAINT 6:
? 15.8 80.8 .74


                    INITIAL OPTIMUM ALLOCATION PLAN

     THE NUMBER OF DIRECT SAMPLES        =     98.9

     THE NUMBER OF INDIRECT SAMPLES      =    671.4

     THE COST OF SAMPLING WITH THIS PLAN = $  830.29

                    VARIANCES OF THE MEANS
            ---------------------------------------------
              VAR 1   VAR 2   VAR 3   VAR 4   VAR 5   VAR 6
            ---------------------------------------------
   SPECIFIED    .24    3.14     .28     .04     .06     .74
   ESTIMATED    .21     .64     .11     .02     .06     .28


   HOW MANY SAMPLING PLANS DO YOU WANT
   ? 5
   ENTER THE COST OF EACH PLAN
   (SEPARATED BY A COMMA OR A SPACE)
   ? 700 600 500 400 300


                    OPTIONAL OPTIMUM ALLOCATION PLANS

            COST       SAMPLES             VARIANCES OF THE MEANS
          --------   -----------   ---------------------------------------------
          DOLLARS     N1     N2    VAR 1   VAR 2   VAR 3   VAR 4   VAR 5   VAR 6
          --------   -----------   ---------------------------------------------
SPECIFIED VARIANCES                 .24    3.14     .28     .04     .06     .74
OPTIONAL PLANS

   PLAN 0  830.29    98.9  671.4    .21     .64     .11     .02     .06     .28

   PLAN 1  700.00    83.4  566.0    .25     .76     .13     .02     .07     .33

   PLAN 2  600.00    71.5  485.2    .30     .89     .15     .02     .08     .39

   PLAN 3  500.00    59.6  404.3    .36    1.07     .18     .03     .09     .47

   PLAN 4  400.00    47.7  323.4    .45    1.34     .22     .04     .12     .58

   PLAN 5  300.00    35.7  242.6    .59    1.78     .29     .05     .15     .78
```

Fig. 1. *Computer printout from program DUBSAM.*

Table 1. Statistical analysis of the double sampling data. Regression of clipped green weight against estimated green weight.

Species	Sample size	Clipped green weight (gm) Mean	Clipped green weight (gm) deviation	Standard deviation about the regression line
Bouteloua gracilis (H.B.K.) Lag. ex Steud.	50	4.90	10.60	2.35
Sporobolus cryptandrus (Torr.) A. Gray	50	17.74	14.80	6.07
Aristida spp.	50	5.32	6.14	2.41
Sphaeralcea coccinea (Pursh) Rydb.	50	2.10	2.61	0.94
Chenopodium spp.	50	2.37	4.30	1.82

The average time needed to clip a plot was 10 times higher than that needed to ocularly estimate a plot. On the average, 15 plots were clipped per day. The daily wage of a skilled person was assumed to be $75. This gave a cost of $5 for obtaining one clipped plot and $.50 for estimating one plot ocularly.

This information was used in formulating the objective function. The quantities V_n and V_n' in the left-hand side of the constraints were calculated using equation (8). The right-hand side of the constraints, or the precision specifications, were obtained from the test data using equation (17). A 10% CV for the estimated means to be obtained was specified.

Based on these calculations, the test problem was of the form.

$$\text{Minimize Cost} = 5n + .5n'$$

subject to

$5.5/n + 106.8/n' \leq .24$ (constraint for *Bouteloua gracilis)*

$36.8/n + 182.2/n' \leq 3.14$ (constraint for *Sporobolus crytandrus*)

$5.8/n + 31.8/n' \leq .28$ (constraint for *Aristida* spp.)

$0.9/n + 5.9/n' \leq .04$ (constraint for *Sphaeralcea coccinea*)

$3.3/n + 15.2/n' \leq .056$ (constraint for *Chenopodium* spp.)

$$n' > n > 0.$$

Solution to this problem was obtained using the program DUBSAM (Ahmed and Bonham 1980). The computer printout is given in Figure 1.

The most important binding constraint(s) may not be important practically. For a practical solution of the tolerance setting, a series of sampling plans for varying costs and degrees of precision can be worked out. The sampler can then choose the plan which best fits the particular budget and precision requirements.

The program was written for solution of problems with up to 10 constraints (species). It can, however, be modified to handle more than 10.

For the test problem, the number of direct samples (n) was 99 and that of indirect samples (n') was 672. The cost of sampling with this plan, excluding the fixed cost, was $830.29 (Figure 1). Optional plans for variable costs of $700, $600, $500, $400, and $300 were also obtained. With an allocation plan up to the cost of $400, only the precision requirements for *Bouteloua gracilis* and *Chenopodium* ssp. were violated. With a plan cost of $300, all the precision requirements except that of *Sporobolus cryptandrus* were violated. The optimum ratio of clipped plots to ocularly estimated plots was 6.6 (672. ÷ 99) (Fig. 1).

Conclusions

The optimum allocation problem in multivariate double sampling can be solved by analytical or graphical methods as described by Ahmed and Bonham (1980). However, the computer can be used more conveniently to obtain the solution of the optimum allocation problem and sampling plans for specified costs.

The constraints most binding may not be important practically. For a practical solution of the tolerance setting, develop a series of plans for varying costs and degrees of precision. Then the plan which best fits in terms of the budget and precision requirements can be chosen.

Although the principles and methods are generally applicable, the data obtained and presented here are applicable only to the specific site sampled and for the year. This technique for optimum allocation in multivariate double sampling for biomass estimation is not restricted in its use. The technique will be found useful in all situations of double sampling and in all fields of study where the interest is in finding optimum allocation of resources for taking direct and indirect measurements on one or more variables. This technique will also be found useful in stratified sampling. In stratified double sampling, optimum allocation can be worked out for each stratum, and the information so collected can then be pooled for estimating population parameters.

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Response of Livestock to Riparian Zone Exclusion

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Abstract

Fencing has been proposed as the best alternative for rapid restoration of streamside riparian zones. In this study the major portion of the streamside riparian zone was excluded by fencing. Use by cows with calves and by yearlings was evaluated on the remaining portion of the riparian and upland zones during the summer grazing season. Regardless of aspect, both classes of livestock generally selected the riparian zone over the uplands throughout most of the summer grazing season. Both classes of livestock reversed their selection in favor of upland vegetation in the latter part of the season. Slopes less than 35% were preferred throughout the grazing season. Cows were more selective in use of certain plant communities than yearlings and, contrary to usual findings, distributed themselves over the range better than yearlings. Neither salt placement nor alternate water location away from the riparian zone influenced livestock distribution appreciably.

Throughout the Pacific Northwest, riparian zones make up a small part of the total land base, yet receive a disproportionately large part of the resource in forest use (Thomas et al. 1979). Due to the favorable moisture, riparian zones surpass other habitats in terms of productivity and use. Recreation, timber harvest, road and railroad construction, and grazing by both wildlife and domestic livestock have a dramatic impact on this highly productive zone.

Land managers are under pressure to improve water quality and maintain or enhance anadromous fisheries. The Federal Water Pollution Control Act (1972) requires that by 1983, all waters on public lands will be suitable for recreation and propagation of fish, shellfish, and wildlife; and the elimination of pollutant discharge into navigable water will be required by 1985. The 1972 Act also stipulates that the Environmental Protection Agency will be responsible for monitoring sources of point and non-point pollution. All animals on open ranges are a potential source of non-point pollution.

The literature of range management is essentially devoid of information specific to the management of riparian zones. The impacts associated with livestock grazing in the riparian zone have become a subject of controversy in recent years (Carothers 1977). Potential solutions to preconceived problems are only now being formulated and tested.

Cattle *(Bos taurus)* prefer the diversity, quality, and succulence of vegetation found in riparian zones (Ames 1977). The relationship between the microclimate of an area and cattle use is not well documented.

The common solution has been to fence livestock out of the riparian zone. This approach is expensive, both in terms of fencing costs and loss of forage. Other less drastic approaches, if successful, would be preferred. This study is part of a larger effort to accumulate information essential to development of livestock grazing systems that could protect riparian vegetation from overuse by cattle.

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The objectives of this study were to:

1. Determine differences in use patterns of yearling cattle and of cows with calves in pastures containing both riparian and upland mountain range plant communities,
2. Evaluate behavioral responses of cattle that are excluded from the riparian zone by fencing,
3. Determine differences in use between yearlings and cow-calf pairs between cover types on north and south aspects, and
4. Determine differences in 1, 2, and 3 above due to the periods within the grazing season (time periods I, II, and III).

Study Area

The study was conducted in the Blue Mountains of northeast Oregon, on the 12,000-ha Starkey Experimental Forest and Range, 48 km southwest of La Grande, Union County. The area is normally grazed from mid-June until mid-October by 800 animal units belonging to five permittees. The area used in this study included 345 ha representative of the general mix of upland and riparian zones of the area.

The vegetation is typical of mountainous rangelands of the Blue Mountains and has been described by Strickler (1965) and Driscoll (1955).

Elevations range from 1,067 to 1,524 m. Annual precipitation averages 50 cm, of which 90% falls as spring and fall rains or winter snow. July and August are the driest months. Frost can occur

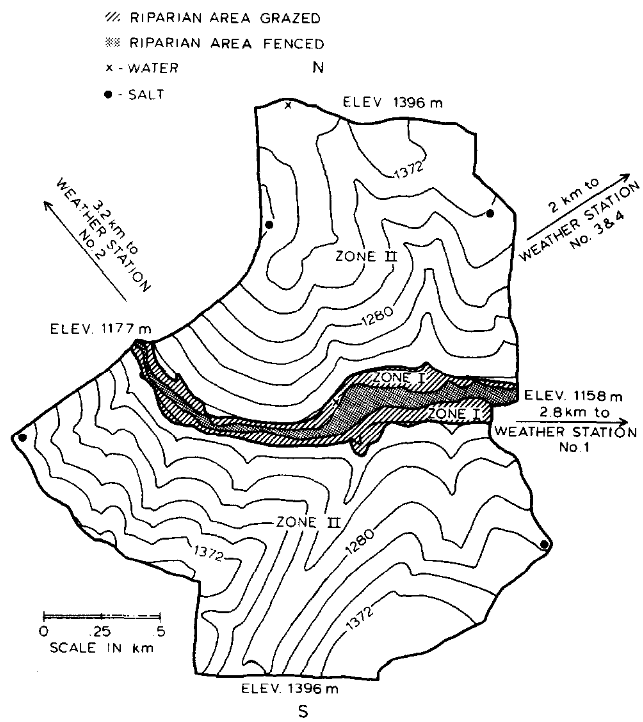

Fig. 1. *Outline map of study area.*

during any month (Driscoll 1955).

Soils are predominantly silt loams with parent materials of basalt, ash, basaltic alluvium, and lacustrine deposits. Soil depth varies from 10 cm on the grasslands to 122 cm under forests on the north slopes (Soil Conservation Service and USDA Forest Service 1960).

The study area consisted of two pastures separated by a stream and riparian zone which was fenced into a corridor (Fig. 1). The north pasture comprised 154.32 ha on a south aspect, and the south pasture contained 190.40 ha on a north aspect. Elevations ranged from 1,158 to 1,396 m.

The plant communities within the pastures were defined by Ganskopp (1978) and were grouped to coincide with Hall's (1973) plant communities of the Blue Mountains (Table 1).

The pastures were divided into riparian (zone I) and uplands (zone II). Most of zone I was fenced to exclude livestock. A small strip of zone I remained accessible between the fence and the toe of the slope (Table 1). The remainder of the pastures were included in zone II (Fig. 1). Not all of the vegetation in zone I demonstrated influence of free water, but other environmental factors characteristic of the riparian zone, such as microclimate, were present. The zone I–II boundary was defined by a distinct ecotone between plant community types.

Table 1. Plant communities, their area composition, and their estimated production.

Plant community types	Composition (Hectares)	(Percent)	(Kg/ha)[1]
North Pasture (154.32 hectares)			
1. *Poa sandbergii*/*Danthonia unispicata*	1.08	.70	179
2. *Artemisia rigida*/*Poa sandbergii*	T[2]	T[2]	232
3. *Agropyron spicatum*/*Poa sandbergii*	60.39	39.13	407
4. *Festuca idahoensis*/*Eriogonum heracleoides*	.39	.25	336
5. *Pinus ponderosa*/*Agropyron spicatum*	2.59	1.68	480
6. *Pinus ponderosa*/*Festuca idahoensis*	4.87	3.16	402
7. *Pinus ponderosa*/*Symphoricarpos albus*	5.39	3.49	430
9a. *Pseudotsuga menziesii*/*Symphoricarpos albus*[3]	5.62	3.64	430
9b. *Pseudotsuga menziesii*/*Symphoricarpos albus*	48.38	31.35	430
10. *Abies grandis*/*Linnaea borealis*	24.49	15.87	233
11. Wet meadow[4]	.26	.17	2464
12. Dry meadow[4]	.86	.56	896
South Pasture (190.40 hectares)			
1. *Poa sandbergii*/*Danthonia unispicata*	1.17	.61	179
2. *Artemisia rigida*/*Poa sandbergii*	T[2]	T[2]	232
3a. *Agropyron spicatum*/*Poa sandbergii*[3,4]	1.04	.55	407
3b *Agropyron spicatum*/*Poa sandbergii*	15.03	7.89	407
4. *Festuca idahoensis*/*Eriogonum heracleoides*	12.13	6.37	336
5. *Pinus ponderosa*/*Agropyron spicatum*	4.70	2.47	480
6. *Pinus ponderosa*/*Festuca idahoensis*	3.88	2.04	402
8. *Pseudotsuga menziesii*/*Physocarpus malvaceus*	26.05	13.68	332
9. *Pseudotsuga menziesii*/*Symphoricarpos albus*	26.96	14.16	430
10a. *Abies grandis*/*Linnaea borealis*[3,4]	6.40	3.36	233
10b. *Abies grandis*/*Linnaea borealis*	91.54	48.08	233
11. Wet meadow[4]	1.37	.72	2464
12. Dry meadow[4]	.13	.07	896

[1]According to Hall (1973).
[2]Trace, not measurable.
[3]Although 3a, 9a, and 10a plant communities did not differ in their floristic composition from 3b, 9b, and 10b, they were statistically treated as different communities because of their location in respect to the riparian zone.
[4]Denotes that these plant communities either occurred in the riparian zone or directly adjacent to it.

Water for livestock was found throughout the south pasture. The north pasture contained two water sources, both constructed ponds. One was located in zone I and the other on a ridgetop in Zone II (Fig. 1).

Two salt sources per pasture were placed on ridgetops in pasture corners farthest from zone I (Fig. 1).

Weather data were available from four stations located near the study area (Fig. 1). However, only data from stations 1 and 3 that were located under conifer canopy cover were analyzed.

Methods

The study was designed to determine cattle movements over two aspects, with two classes of livestock, using two different vegetation zones. The grazing season was divided into three time periods (July 20–August 12 (I), August 16–September 9 (II), September 13–October 7 (III)). Three observation days of 6 hours each (0400–1000, 1000–1600, 1600–2200 hours) were conducted in each pasture each week. During these observation days, one animal in each pasture was kept under constant observation and its location was plotted on an aerial photo at 30-minute intervals. Although plotted locations at 30-minute intervals did not represent totally independent observations, they were treated as such in the analysis.

On June 30, the north pasture was stocked with 10 cows with calves and the south pasture with 15 yearling heifers. The cows were Hereford and Hereford-Angus crosses and the yearlings were Hereford-Angus crosses. Cattle were rotated between pastures every 2 weeks so they spent equal time in each pasture. The phenological condition and availability of plants to graze remained relatively equal between rotations. Each class of livestock was given a 2-week adjustment period in each pasture before the study began. Thus, the grazing season was divided into 3 time periods with 6 observation days occurring every 2 weeks in each pasture.

Five cows and 5 yearlings were marked with collars to insure identification. One cow and 1 yearling were randomly selected and observed throughout each 6-hour observation day. Monday or Tuesday was randomly selected each week as the starting day. One of the 3 observation days was randomly selected each week, and the other 2 observation days followed in sequence until all 6-hour days were completed. Observations of cows and yearlings in the separate pastures were made simultaneously. Each animal's location was identified as to plant community type, slope, zone, and distance to water and salt.

There are different total numbers of observations (Table 2) between cows and yearlings because of the problem in locating the random selected animal at the start of observation periods.

Chi-square, analysis of variance, and Student's t-tests at the 0.10-level of probability were employed to test hypotheses concerning nonrandomness of distribution of the cattle in response to the previously mentioned independent variables. Chi-square contingency tests were used to test independence between two factors, cows and yearlings. A Chi-square heterogeneity test was used to test the randomness of animal response to independent variables. Tukey's separation of means test (Steel and Torrie 1960) was used to differentiate between variables when analysis of variance indicated that differences existed.

The plant community types 1-2, 3-4, 5-6-7 in the north pasture and 1-2-4, 5-6, 8-9 in the south pasture (Table 1) were pooled into larger but still identifiable units because expected values within the types were too small for appropriate use of Chi-square procedures (Steel and Torrie 1960).

Results and Discussion

The differences in patterns of use between time periods by cows and by yearlings and between cows and yearlings was a response interaction among the vegetation's phenological condition, grazing preference, and climatic changes.

Plant Community Types

Cows and yearlings spent a disproportionate amount of time in

Table 2. The observed and χ^2 expected values of cows and yearlings in each plant community type (Table 1), in each pasture, in each time period.

Plant community types	Cows Obs.	Cows Exp.	Yearlings Obs.	Yearlings Exp.	Cows Obs.	Cows Exp.	Yearlings Obs.	Yearlings Exp.	Cows Obs.	Cows Exp.	Yearlings Obs.	Yearlings Exp.
	Time period I[1]				Time period II[1]				Time period III[1]			
North Pasture												
1–2	0	0.3	0	0.4	0	0.3	0	0.4	0	0.1	2	0.4
3–4	1	22.0	6	24.4	19	22.0	0	26.4	19	7.5	41	24.0
5–6–7	0	4.7	1	5.2	2	4.7	0	5.6	0	1.6	9	5.1
9a	24	2.0	27	2.3	20	2.0	47	2.4	0	0.7	0	2.2
9b	14	17.6	8	19.4	6	17.6	8	21.0	0	6.0	9	19.1
10	0	8.9	0	9.8	0	8.9	0	10.6	0	3.0	0	9.7
11	3	0.1	7	0.1	2	0.1	8	0.1	0	0.03	0	0.1
12	14	0.3	13	0.3	7	0.3	4	0.4	0	0.1	0	0.3
	Time period I[1]				Time period II[1]				Time period III[1]			
South Pasture												
1–2–4	0	4.8	0	3.4	0	4.3	2	4.1	11	4.5	6	1.1
3a	15	0.4	0	0.3	2	0.3	0	0.3	19	0.4	0	0.1
3b	4	5.4	0	3.8	0	4.9	29	4.7	25	5.1	7	1.3
5–6	0	3.1	0	2.2	0	2.8	3	2.6	0	2.9	0	0.7
8–9	0	19.2	0	13.4	0	17.3	11	16.4	2	18.1	3	4.5
10a	21	2.3	6	1.6	15	2.1	0	2.0	1	2.2	0	0.5
10b	26	33.2	0	23.1	9	29.8	14	28.4	7	31.2	0	7.7
11–12	3	0.7	42	0.5	36	0.6	0	0.6	0	0.7	0	0.2

[1]Obs. = Observed
Exp. = Expected value
[1]= Significant difference between cows and yearlings ($P<.10$).

the riparian plant communities regardless of pasture aspect during time period I. Yearlings and cows used the riparian plant communities again in time period II until they were switched and then both selected the upslope plant communities. During time period III, both livestock classes used the upslope communities extensively but selected different plant communities (Table 2).

Cows with calves grazed the most productive forage areas more widely throughout the entire pastures than did the yearlings (Table 1). Although both classes of livestock had a 2-week familiarization period, the cows had grazed the area in previous years and, therefore, were more familiar with it. Greater grazing familiarity on such ranges may have accounted for the wider distribution of cows than yearlings. Cows with calves have greater (per unit of weight) basal metabolic expenditures than yearlings. Maynard and Loosli (1969) described digestible energy requirements as 2,640 kcal/kg for cows and 2,310 kcal/kg for yearlings. There are added energy expenditures for lactating cows. These differences may contribute to the differences in use of plant community types by cows and yearlings. By selecting the more productive plant communities, cows were able to fill their greater energy requirement. Yearlings could evidently fill their lower requirement by remaining on gentler terrain.

On the same study area, Holechek et al. (1978) demonstrated microclimatic effects. He found that cattle weight gains in predominantly forested pastures, during mid-July to mid-September, were .13 kg/day greater than those on predominantly grassland pastures. These gains were not solely attributed to the higher nutritional quality of the forage in the forested pastures, but also to the cooler microclimate that allowed them to graze longer each day.

Both cows and yearlings used the timber type plant communities more than the upland grassland plant communities during period II. Besides microclimate, grass and grasslike plants on the forested sites have more crude protein and less lignin than those in grassland pastures during this period (Pickford and Reid 1948, Holechek et al. 1978).

Environmental Conditions

Differences between stations 1 and 3 in mean daily ambient temperature and mean percent relative humidity recordings were tested by Student's *t*-tests (Fig. 2). During period I, there were differences in mean ambient temperature ($P<.001$) and mean percent relative humidity ($P<.001$) between stations 1 and 3. During period II there was also a difference between stations in mean ambient temperature ($P<.10$) and mean percent relative humidity ($P<.001$). During period III, however, there was no difference between stations in mean ambient temperature ($P<.10$) while there was a difference in mean percent relative humidity ($P<.001$).

There was a difference in zone selection between cows and yearlings (Table 4). Yet, during periods of higher mean ambient temperature and lower mean relative humidity on the upslopes, both classes moved to zone I regardless of pasture aspect. When the mean ambient temperature decreased and the mean-percent rela-

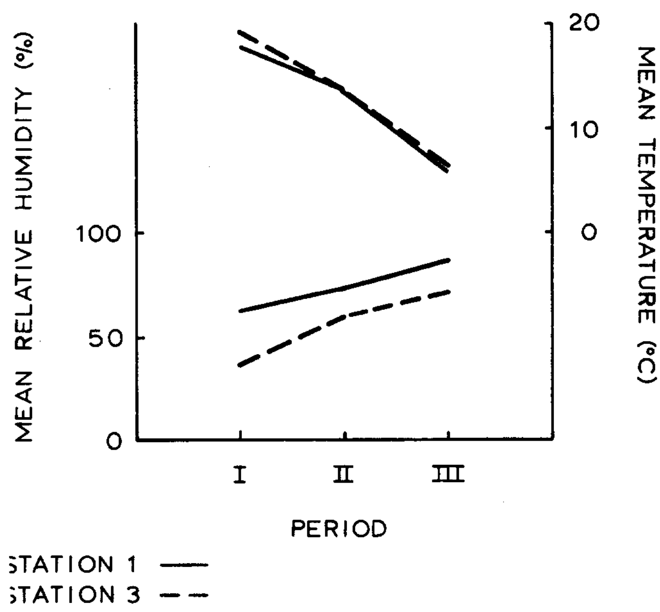

Fig. 2. *Mean temperature and relative humidity by sample periods.*

Table 3. The observed and χ^2 expected values of cows and yearlings in each slope class, in each pasture, in each time period, and the amount of pasture in slope class percent.

Slope classes	Percent of pasture	Cows Obs.	Cows Exp.	Yearlings Obs.	Yearlings Exp.	Cows Obs.	Cows Exp.	Yearlings Obs.	Yearlings Exp.	Cows Obs.	Cows Exp.	Yearlings Obs.	Yearlings Exp.
		Time period I[1]				Time period II[2]				Time period III[2]			
North Pasture													
1≤20%	21.5	41	12	41	13	29	12	43	14	3	4	10	13
2=21-35%	33.2	0	19	13	21	10	19	14	22	16	6	51	20
3=36-50%	22.3	11	12	1	14	15	12	8	15	0	4	0	14
4=51-75%	23	4	13	7	14	2	13	2	16	0	5	0	14
5≥75%	t	0	0	0	0	0	0	0	0	0	0	0	0
		Time period I[1]				Time period II[1]				Time period III[1]			
South Pasture													
1≤20%	11.7	21	8	42	5.6	37	7	27	7	18	8	10	1.9
2=21-35%	16.2	20	11	0	7.8	11	10	13	10	28	10	6	2.6
3=36-50%	59.8	17	41	6	28.7	13	37	6	35	14	39	0	9.6
4=51-75%	12.3	11	9	0	5.9	1	8	13	7	5	8	0	2.0
6≥75%	t	0	0	0	0	0	0	0	0	0	0	0	0

[1]=significant difference between cows and yearlings ($P<.10$).
[2]=No significant difference between cows and yearlings ($P>.10$).

tive humidity increased in zone I, both cows and yearlings moved upslope to zone II.

Ungulates have few mechanisms by which to control body temperature. They can do one or more of the following things to cope with excessive heat: (1) accelerate respiration; (2) consume water; (3) restrict movements or rate of movement; (4) seek more comfortable environmental conditions; or (5) perspire through relatively insufficient apocrine sweat glands. All of these actions tend to reduce the metabolic rate.

Figure 2 shows that the temperature was cooler and the humidity higher in the riparian zone during time period I. Both cows and yearlings selected zone I over zone II. Slopes of less than 20%, a cooler microclimate, available water, and available forage quantity and quality apparently combined to produce a more desirable situation.

The dramatic change in both cow and yearling use of plant community types, slope, and zones in time period II was influenced by forage quality and quantity during this period and also by thundershower activity. On the two occasions when thundershowers produced 1.27 mm and 4.83 mm of precipitation, both cows and yearlings moved from zone I to zone II.

During period III, both classes of livestock largely avoided zone I. In the north pasture, both cows and yearlings avoided zone I. In the south pasture, however, the yearlings avoided zone I while the cows made disproportionately heavy use of zone I. Some of this change could also be attributed to the two thunderstorms that produced .5 mm and 2.29 mm of precipitation.

During period III, there were no significant differences in mean ambient temperature between weather stations 1 and 3 (Fig. 2) but there was a much higher mean percent relative humidity in the riparian zone. In addition, available forage was greatly reduced in zone I due to grazing and the vegetation in zone II had received little use. The vegetation in zone II was cured, but precipitation had stimulated regrowth and softened the cured vegetation making it more palatable.

Overall, mean-percent relative humidity appeared to have more influence on livestock distribution than temperature. Both cows and yearlings preferred zones where the relative mean humidity was 60–70% regardless of temperature (Table 4 and Fig. 2). Enrenreich and Bjugstad (1966) explained spring cattle grazing activity in the Missouri Ozarks in a similar manner.

Effect of Slope

Cows used more slope classes and plant community types than yearlings (Table 3). As slope increased, frequency of use by both livestock classes decreased (Table 3). Phillips (1965), Glendening (1944), Hedrick et al. (1968), and Mueggler (1965) have reported similar results.

Both cows and yearling selected areas with slopes less than 35% in both pastures. Some 54% of the north pasture had slopes less than 35% that received 85% of the livestock use. In the south pasture, 28% of the area had slopes of less than 35% and received

Table 4. The observed and χ^2 expected values of cows and yearlings in each zone, in each pasture, in each time period, and the percent of each zone in each pasture.

Zones	Percent of pasture	Cows Obs.	Cows Exp.	Yearlings Obs.	Yearlings Exp.	Cows Obs.	Cows Exp.	Yearlings Obs.	Yearlings Exp.	Cows Obs.	Cows Exp.	Yearlings Obs.	Yearlings Exp.
		Time period I[1]				Time period II[2]				Time period III[1]			
North Pasture													
I	4	41	2	47	2.7	29	2	59	2.9	0	0.8	0	2.6
II	96	15	54	15	59.3	27	54	8	64.1	19	18.2	61	58.4
		Time period I[2]				Time period II[2]				Time period III[2]			
South Pasture													
I	5	39	3.2	48	2.3	53	2.9	0	2.8	20	3.1	0	0.75
II	95	30	65.8	0	45.7	9	59.1	59	56.2	45	61.9	16	15.25

[1]=Significant difference between cows and yearlings ($P>.10$).
[2]=Significant difference between cows and yearlings ($P<.10$).

71% of the livestock use (Table 3).

This is contrary to the observations of Hedrick et al. (1968:4) made under roughly similar conditions in the Blue Mountains. They stated that . . . "Young animals. . . .use[d] these rough timbered areas most efficiently. A ranking to show different classes of cattle in declining order of suitability for these areas is as follows: Steers, replacement heifers, young cows with grazing experience in [the] area as heifers, old cows without calves, and regular cows and calves." No data was presented in support of this contention.

Hickey and Garcia (1964), working with cattle distribution and forage utilization on non-forested ranges in New Mexico, concluded that, "Yearling cattle utilize grasses more uniformly over variable terrain than . . . cows with calves. . . .On rough terrain more uniform utilization may be attained by grazing with yearling heifers. . . ." Data were presented to support this contention.

There is no satisfactory way to explain the differences in the distribution patterns of cows with calves and yearlings reported here and those reported by Hedrick et al. (1968) and Hickey and Garcia (1964). In future studies, we will pay particular attention to this aspect of livestock behavior.

Water

Free water was available in zone I and the extreme upper end of the north pasture (zone II) (Fig. 1). Table 5 illustrates the influence of water on the distribution of cows and yearlings during each time period. During time period I, the cows remained closer to water than did yearlings. This can probably be attributed to the cow's greater need for water caused by body size and lactation. In time period II, there was no statistical difference between cows and yearlings, in terms of their distance from water. Their activities and behavior, however, were altered by the thundershower activity. At the beginning of this time period, cows stayed closer to water and then increased their distance from it. However, yearlings distributed themselves closer to the water than cows and maintained that distance throughout the period (Table 5). The yearlings were in the pasture before the thundershower activity, and the cows were present during the thunderstorms.

In time period III, water was ineffective in distributing cows or yearlings. Although there was a difference in how cows and yearling were distributed, they both responded similarly to the progression of the grazing season (Table 5). This could be attributed to the cooler temperatures (which influenced water consumption rates), fall regrowth, softening of the cured forage, and/or a decrease in lactation production by cows.

Water in the upper end of the north pasture (Fig. 1) received little use by either cows or yearlings until time period III. The cows were exposed to the upper water source when they were initially introduced to the pasture. Although it seemed likely that this water source might attract the cows (and away from the riparian zone) for a short time, it did not. The cows were introduced into the pasture at this water source in the late afternoon and by early morning they were in zone I.

Table 5. Mean distance in meters from nearest salt and water source by cows and yearlings.

	Time period I		Time period II		Time period III	
Attractants	Cows[1]	Yearlings[1]	Cows	Yearlings	Cows	Yearlings
North Pasture[2]						
Salt[2]	832	806	754	897	442	390
Water[2]	260	351	481	442	845	676
South Pasture						
Salt[2]	845[3]	767[4]	793	1027	793	871

[1]Significant difference between time periods I-II, I-III, and II-III ($P<.10$) for both cow and yearlings.
[2]Significant differences between cows and yearlings when the 3 periods were pooled.
[3]No difference between time periods ($P>.10$) for cows.
[4]Significant difference between time periods, I-II, I-III, and II-III ($P>.10$) for yearlings.

Provision of water is usually considered the most important tool for influencing distribution of livestock (Cook and Jefferies 1963, Glendening 1944, Martin and Ward 1970). Because of the availability of water in the riparian zone and the necessity for cattle to negotiate steep slopes to reach the upper elevation water source, such was not the case here. Findings suggest that water is much less effective for influencing cattle distribution in areas where water is present in the already disproportionately attractive riparian zone.

Salt

Though there was a difference in the way cows and yearlings distributed themselves in relationship to salt, it was not effective in altering distribution between livestock classes (Table 5). During time period III, the cattle moved from zone I to II. This move put them closer to salt, but they appeared not to be influenced by the salt *per se*. The behavior in time period III contrasted to that in periods I and II. It was anticipated that salt consumption would be highest during the early grazing season when forage plants were most succulent. Cattle probably choose not to expend the energy necessary to climb out of the canyon bottom to obtain the salt. Once they moved out of the canyon bottom in response to other factors, they did use some salt which is similar to what Cook (1966) found.

These cattle used the salt when convenient but did not alter behavior patterns to obtain it. There did appear to be some relationship between cattle movement and salt use during time period II. This was related to general movements from zone I to II during thundershower activity.

Martin and Ward (1973, p. 96) reached these conclusions:

> Placing salt or meal-salt mixture on remote parts of the range where forage is abundant will increase utiliztion of perennial grasses in such areas but will not greatly decrease use on areas closer to water.
>
> Placement of salt or meal-salt alone cannot be expected to cure a serious distribution problem. . . .

Skovlin (1965) suggested that range cattle required little supplemental salt in addition to that present in forage, but their appetite compels them to use it as a condiment. Hedrick et al. (1968) contended that salting in other than supplemental forms had little effect on livestock use patterns in mixed coniferous forest types. Morris and Murphy (1972) maintained that salt requirements of cattle have not been demonstrated.

Conclusions

The following conclusions are preliminary in that the study was conducted for 1 grazing season in 2 pastures. Pasture configuration may also have influenced distributional patterns.

Cows and yearlings concentrated their use in the riparian zone. This resulted from comfort (microclimate), energy conservation, availability of succulent vegetation, or a combination of these factors. Lower temperatures and higher relative humidity occurred in zone I in time periods I and II. Cows used more plant community types regardless of aspect than did yearlings, with concentration on the more productive of these types.

Slopes less than 35% were preferred by both classes of cattle regardless of pasture aspect. The cows made more use on the steeper slope classes in both pastures, however, than did yearlings.

Salt placement in upper portions of the pastures did not induce cattle to use these areas nor did it reduce cattle concentrations on riparian communities. Manipulation of access to water as a means of controlling cattle use of riparian zones needs further research to determine its effectiveness in increasing livestock distribution.

Leaving a portion of the riparian zone available to cattle exposed a very attractive plant community type of which livestock demonstrated a high preference. Eliminating access to water near this area would probably have lessened the problem of cattle concentrations.

Recommendations

Data suggest that because of limited use of slopes over 35%, a case-by-case determination of cattle stocking rates should be considered.

When forage-rich riparian zones are available at the bottom of narrow canyons, they are attractive to cattle and concentrate their activity. This feature should be carefully considered when preparing a range management plan or implementing practices.

When fencing riparian zones to exclude livestock, care should be taken to insure that all riparian plant community types are included. To eliminate livestock concentrations in the riparian zone it might be better to place the fence on the first flat area above the stream.

Conditions of temperature and relative humidity in late season (period III) produced a less comfortable environment in canyon bottom riparian zones and more comfortable environments on the upslopes. It is possible, therefore, that stocking pastures with riparian zones during the cooler part of the grazing season would lessen cattle impacts.

Cows with calves used more slope classes and more plant communities than did yearlings—i.e., cows can be assumed to have better and more complete utilization of available forage than do yearlings. Cows with calves should be stocked, in preference to or in combination with yearlings, to increase distribution and, in turn, utilization of forage in pastures with the characteristics of those found in the study area.

In summary, in the study area pastures, inclusion of pastures with riparian zones as separate units in a rotation grazing system and by grazing these pastures late in the grazing season by cows with calves will produce the best use of the upland forage resources. In turn, this treatment should reduce grazing impact on the riparian zone.

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Production and Nutritive Value of Aspen Understory, Black Hills

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Abstract

Production of and nutrient concentrations in understory vegetation was measured in aspen stands representing three different seral stages in the Black Hills. There was little variation in concentrations of nutritive elements in the same plant species among stands. Differences in species composition and shrub, forb, grass, and total production caused some variation in total available nutrients. Production of aspen understory, while variable (676-1226 kg/ha), was one of the higher producing types in the area. Digestible dry matter, fiber, lignin, and calcium were at acceptable levels for white-tailed deer growth. Protein and phosphorus concentrations may be considered marginal, but variation in concentrations among plant species, the large number of plant species available, and the selective feeding habits of deer may preclude nutrient deficiencies in their diet. The value each of the seral stages has to livestock and wildlife is discussed and management suggested.

Quaking aspen *(Populus tremuloides)* stands have been recognized as important to many wildlife species and to livestock because of the diversity they create in otherwise homogeneous conifer stands and for the variety and productivity of understory vegetation (Reynolds 1969, Kranz and Linder 1973). Understory production has been studied in several areas of the West, including Utah (Ellison and Houston 1958, Cook and Harris 1968), Colorado (Paulsen 1969), Arizona (Reynolds 1969), South Dakota (Kranz and Linder 1973), and Wyoming (Bartos and Mueggler 1981). Selected nutritive characteristics have also been reported by Cook and Harris (1968) and Paulsen (1969).

Aspen, however, generally is considered a seral stage that will gradually be replaced by conifers (Jones 1974) with few exceptions (Severson and Thilenius 1976, Mueggler 1976). Studies thus far have not related the seral stage of aspen to understory productivity or nutritive content. This study examines these parameters in aspen stands that represented different successional stages.

Study Area

The study was conducted in the Black Hills of western South Dakota and northeastern Wyoming. Specific study sites were selected from aspen groups as defined and described by Severson and Thilenius (1976), who separated aspen stands of the Black Hills into 9 homogeneous groups by cluster analysis of a similarity matrix based on physical site, soil, and vegetation characteristics. Three groups that contained the largest number of stands and also represented different seral stages were selected for production and nutrient analysis. Group 1 was comprised of 8 stands, and was characterized by a very high average density of small diameter (<10.2 cm d.b.h.) aspen stems. Average age was 28 years. Most sites in group 1 had burned 31 to 39 years ago. The successional status (seral versus relatively stable) of stands in this group could not be determined because they were too young. This group will be called the young group.

Aspen group 3 contained 7 stands made up of larger trees (10.2-20.3 cm d.b.h.) as well as the smaller size class (<10.2 cm d.b.h.) at about one-fifth the density of stands in the young group. Average stand age was 61 years. Most sites had burned 60 to 80 years ago. Ponderosa pine *(Pinus ponderosa)* and white spruce *(Picea glauca)* were invading in significant amounts which indicated significant progress towards an eventual conifer climax. This group will be called the mid-age group.

Aspen group 5 supported stem densities intermediate to the previous groups, with about one-half as many trees in the 10.2–20.3 cm d.b.h. class as in the smaller size class. Most stands were young, 15 to 19 years old. This group also differed from the others in that it had a herbaceous understory dominated by rhizomatous or stoloniferous species. The lush nature of the understory and close proximity to water encouraged use by cattle. The sod and presence of cattle combined to suppress both conifer reproduction and aspen suckering, thus complicating the normal successional process (Severson and Thilenius 1976). This group will be called the altered group.

Methods

Two aspen stands were randomly selected from each of the three described groups. Two 38 × 38 m macroplots were randomly established within each stand and fenced to prevent grazing by cattle. White-tailed deer *(Odocoileus virginianus)* occasionally grazed the plots, but use was insignificant. A 30.5 × 30.5 m area within the macroplot was sampled, leaving a buffer strip 3.75 m wide around the periphery.

Production of current annual growth of the woody and herbaceous understory was measured at its peak in late July to early August of 1972 and 1973 using a double-sampling technique called the dry weight prediction method (Blair 1959). Green weights were estimated by species on 60 randomly selected, 30.5 × 60.9 cm plots in each macroplot. Vegetation on 12 of these plots, also randomly selected, was clipped, oven-dried, and weighed. A linear regression quantified the relationship of oven-dried weight (Y) to estimated green weight (X).

The composite shrub, forb, and grass categories used for nutrient analyses reflected their proportional presence in the understory. Samples included material from each species in the same proportion that they occurred in the total production of that class. The four individual species analyzed, three shrubs and one forb; common snowberry *(Symphoricarpos albus),* shinyleaf spirea *(Spiraea lucida),* Wood's rose *(Rosa woodsii),* and cream peavine *(Lathyrus ochroleucus)*—are important summer foods for white-tailed deer (Schneeweis et al. 1972) and were found in all plots.

All samples were analyzed for digestible dry matter using the 2-stage in vitro technique (Tilley and Terry 1963) with inocula from 12 adult white-tailed deer that were collected on summer range that had extensive aspen stands. Crude protein, ash, calcium, and phosphorus were determined by standard laboratory procedures (Association of Official Agricultural Chemists 1965). Acid detergent fiber and acid detergent lignin were determined through procedures developed by Van Soest (1963).

Stands within each group were categorized by cluster analysis using vegetation characters as partial criteria (Severson and Thilenius 1973). Therefore, the groups are already known to be different and statistical analysis based on randomization is inappropriate.

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Table 1. Understory production of selected species and vegetation classes in three aspen groups, Black Hills, South Dakota and Wyoming, 1972 and 1973. Expressed as kg/ha±standard deviation, oven-dried weight.

Year	Aspen group	Species/forage class							Total
		Snowberry	Spirea	Wood's rose	Peavine	Other shrubs[1]	Other forbs[2]	Grasses	
	Young	38± 10	27±19	47±28	28±19	402± 96	174± 47	172± 71	887± 77
1972	Mid-aged	23±13	43±13	7± 5	24±14	182±102	261± 59	136± 29	676± 81
	Altered	36±10	6± 6	22±11	14±14	71± 32	431± 59	646±115	1,226±125
	Young	32± 7	28±11	39±28	17±15	406± 56	101± 11	176± 39	800± 76
1973	Mid-aged	19±11	43±13	10± 6	21± 6	231±211	235± 72	179± 27	738±160
	Altered	27±10	4± 3	20±10	15±15	49± 21	326± 44	489± 81	931± 57

[1]Excluding snowberry, spirea, and Wood's rose.
[2]Excluding peavine.

Several within-group comparisons of nutrient concentrations were made using analysis of variance because selection of stands, macroplots, and production plots was random. No consistent differences were noted among or between most attributes, so only means and standard deviations were tabulated.

Results and Discussion

Forage Production

Relative production of forage classes within and between groups remained consistent over both years, but differences were less pronounced the second year (Table 1). Shrubs produced the most forage in the young group; shrubs and forbs shared dominance in the mid-age group; grasses and forbs were primary producers in the altered group, with grasses predominating. Shrub dominance in the young group was caused in part by the presence of snowbush ceanothus *(Ceanothus velutinus).* Although shrubs and forbs produced most forage in mid-age stands, no single species contributed over 30% of the total amount in either category over both years. Roughleaf ricegrass *(Oryzopsis asperfolia),* however, produced 60% and 65% of the total grass weight over the 2 respective years. Kentucky bluegrass *(Poa pratensis)* and white clover *(Trifolium repens)* accounted for about one-half of the total grass and forb production, respectively, in the altered group.

Production of the selected species important to deer (Table 1) was quite uniform across all groups with only two notable exceptions. Shinyleaf spirea was an insignificant part of the understory in the altered group, and Wood's rose produced little annual growth in the mid-age group even though it was present in all stands (Severson and Thilenius 1976). Total production of these four species was greatest in the young and lowest in the mid-age group in both years.

Forage production in unmanaged aspen stands compares favorably with data from other Black Hills vegetation types. Only the moist meadows dominated by Kentucky bluegrass produced more, 730 to 2,850 kg/ha[1] (Pase and Thilenius 1968); this exceeded the 676 to 1,226 kg/ha reported in Table 1. More xeric meadow types produced from 634 to 1,608 kg/ha[1] (Pase and Thilenius 1968), and heavily thinned immature or sapling (8 to 10 cm average d.b.h.) ponderosa pine stands produced from 1,311 kg/ha (Severson and Boldt 1977) to 1,520 kg/ha[1] (Pase 1958). The dry meadows and lightly stocked, immature pine stands produced forage in quantities comparable to aspen stands. However, more mature, pole-sized (about 15 to 18 cm average d.b.h.) pine stands produced much less forage, regardless of pine stocking levels, as did more heavily stocked sapling stands (Pase 1958, Severson and Boldt 1977).

Understory production in aspen stands does not appear to be controlled by or related to any aspen overstory parameters. Many studies have documented inverse relationships between various overstory characteristics, such as canopy cover, density, and basal area, and understory production in hardwood and softwood stands (Ffolliott and Clary 1972). Such relationships are not evident in stands in which aspen is the sole dominant (Harper 1973, Severson and Kranz 1976). Aspen has the capability of producing large, extensive lateral root systems which can influence understory production (Ellison and Houston 1958). Severson and Kranz (1976) have suggested that the influence of root systems, which may vary in extent and development depending on the number of disturbances to which the stand had been subjected, could mask any effects of the aspen overstory. As conifers invade, however, understory production will decline (Harper 1973). These declines have been significantly related to basal area of the invading conifer and the total basal area, aspen plus conifer (Severson and Kranz 1976). This does not imply that thinning a pure aspen stand will not result in increased production, only that the response will not necessarily be related to overstory parameters. Thinning aspen will result in increased understory, especially grasses, forbs, and aspen sprouts (Reynolds 1969).

[1]Indicates production on an air-dried rather than oven-dried basis.

Understory production in aspen stands is apparently related to the age of the stand—not necessarily chronological age, but seral stage as measured by degree of conifer invasion. Data in Table 1 indicate chronological age might be influential in this respect, but successional rates vary on different aspen sites (Bartos 1973) so aspen stands of different ages could have similar quantities of conifers present. The close association between understory production and coniferous overstory parameters indicate that degree of conifer invasion would be a more reliable indicator of understory potential.

Nutritive Content

There were no significant differences ($P<0.05$) in any nutritive elements between the 2 years, so these data were pooled in Tables 2 and 3. No consistent variations were noted among groups for any nutritive parameter. Most differences within groups were consistent and expected. Forbs were generally more digestible than shrubs, which in turn were significantly more digestible than grasses ($P<0.05$). White-tailed deer, the inocula source, fed almost exclusively on forbs and shrubs during summer (Schneeweis et al. 1972). The lower digestibility of grasses may be a reflection of the adaptability of rumen microorganisms to this diet. Digestibility of shrubs, forbs, and the four selected species ranged between 50% to 60%. This, according to Urness (1973), was excellent for deer.

Forbs contained slightly higher crude protein levels (Table 2), which was partly due to the influence of leguminous species such as cream peavine (Table 3) and clover. Cream peavine was an important protein source for white-tailed deer which required a diet containing 13% to 20% for optimum growth and development (Ullrey et al. 1967). Using Urness' (1973) standards, all composited samples (Table 2) and the other selected species contained only fair protein levels.

Acid detergent fiber levels were significantly higher ($P<0.05$) in grasses than in forbs or shrubs in all groups. Shrubs contained significantly more acid detergent lignin ($P<0.05$). Although no single criteria has been developed to predict digestibility of a ruminant forage item, there is a general, inverse relationship between fiber and lignin content and digestibility. When judged by criteria developed by Urness (1973) fiber contents of common snowberry and Wood's rose were excellent, all others were good except grasses, which rated fair.

Table 2. Nutritive concentrations in composited forage classes, aspen understory, Black Hills, South Dakota and Wyoming. Expressed as percent ± standard deviation of oven-dried weight.

Nutritive element	Forage class	Aspen group		
		Young	Mid-aged	Altered
DDM[1]	Shrubs	54.1±3.7	49.2±3.6	55.8±6.6
	Forbs	59.0±9.4	54.1±3.6	62.8±5.0
	Grasses	41.1±5.3	38.8±3.4	42.8±5.2
Protein	Shrubs	8.3±0.4	8.2±0.7	7.5±0.3
	Forbs	9.1±1.1	8.3±0.6	10.0±1.4
	Grasses	6.4±0.8	7.5±0.4	6.1±0.5
ADF[2]	Shrubs	29.1±2.3	34.0±3.0	31.5±2.2
	Forbs	34.0±2.2	38.1±3.2	31.5±2.8
	Grasses	43.8±3.5	44.6±1.9	42.3±2.4
ADL[3]	Shrubs	10.1±1.7	12.2±1.2	10.0±1.3
	Forbs	7.0±1.1	9.7±0.3	6.2±1.0
	Grasses	5.3±0.5	6.0±0.6	5.1±0.6
Ash	Shrubs	6.7±0.7	5.8±0.5	5.9±0.4
	Forbs	9.3±0.7	9.0±0.9	10.1±1.2
	Grasses	8.7±0.9	9.9±1.3	9.5±1.2
Calcium	Shrubs	1.31±0.19	1.09±0.18	0.92±0.10
	Forbs	1.62±0.15	1.38±0.18	1.54±0.23
	Grasses	0.49±0.11	0.41±0.07	0.51±0.08
Phosphorus	Shrubs	0.29±0.02	0.25±0.03	0.27±0.04
	Forbs	0.22±0.03	0.25±0.03	0.20±0.02
	Grasses	0.20±0.02	0.19±0.02	0.16±0.02

[1]DDM = Digestible dry matter.
[2]ADF = Acid detergent fiber.
[3]ADL = Acid detergent lignin.

Ash is a general measure of total mineral content, but its value in nutrition may be obscured by the presence of quantities of inert material, such as silica (Dietz 1972). Shrubs contained significantly less ($P<0.05$) ash than forbs or grasses. Calcium and phosphorus are two minerals generally reported on an individual basis in forage analyses because both are needed in relatively large quantities (Dietz 1972). In sampled aspen stands (Table 2) forbs had higher calcium concentrations than shrubs; grasses contained the lowest percentages. Phosphorus concentrations were more uniform, but highest percentages were found in shrubs and the lowest in grasses.

There was more variation in calcium concentrations of individual species (Table 3). Cream peavine and Wood's rose in most instances contained a significantly higher ($P<0.05$) concentration of calcium than common snowberry or shinyleaf spirea. Phosphorus percentages were uniform among the three shrubs, but cream peavine had about one-half as much.

Forage classes and individual species all contained levels of calcium that exceeded optimum requirements for white-tailed deer (Ullrey et al. 1973). Phosphorus contents were lower than required in forbs and grasses (Table 2). Selective feeding habits of deer could increase phosphorus intake to an acceptable level because shrubs in general (Table 2) and the 3 important shrub species in their diet (Table 3) contained more phosphorus than the 0.26% recommended for optimum growth by Ullrey et al. (1975).

Calcium:phosphorus ratios are an equally important consideration because excessive calcium can interfere with phosphorus metabolism. A desirable ratio lies somewhere between 1:2 to 2:1, although wider ratios are acceptable if ample Vitamin D is present (Dietz 1972). Ca:P ratios of grasses (2:1) were optimum according to Urness' (1973) criteria. Shrubs as a group and the three shrub species had Ca:P ratios that ranged from 3:1 to 4:1, considered good to fair. Forbs (5:1 to 7:1) and cream peavine (10:1 to 11:1) had ratios that Urness (1973) classified as poor.

Only limited data are available on nutritive values of forage produced in other Black Hills vegetation types. Dietz (1972) reported digestible dry matter, protein, acid detergent fiber, acid detergent lignin, cellulose, ash, calcium, phosphorus, and gross

Table 3. Nutritive concentrations in four selected species from aspen understory, Black Hills, South Dakota and Wyoming. Expressed as percent ± standard deviation oven-dried weight.

Nutritive element	Species	Aspen groups		
		Young	Mid-aged	Altered
DDM[1]	Snowberry	57.0±4.8	54.0±4.5	57.4±7.6
	Spirea	50.4±5.0	46.4±5.4	52.4±5.0
	Rose	52.8±4.2	53.4±5.7	57.2±6.9
	Peavine	52.6±3.2	50.6±4.4	54.9±6.0
Protein	Snowberry	7.5±0.6	7.8±0.4	8.0±1.5
	Spirea	6.5±0.4	6.9±0.5	7.3±0.8
	Rose	7.5±0.5	8.0±0.8	8.2±0.3
	Peavine	15.5±1.4	17.0±1.4	16.7±1.0
ADF[2]	Snowberry	28.2±2.6	28.8±1.3	26.6±1.5
	Spirea	33.1±2.4	32.8±2.1	32.9±2.1
	Rose	25.8±1.8	25.4±2.1	24.2±1.1
	Peavine	34.6±3.3	34.3±1.3	32.9±1.7
ADL[3]	Snowberry	9.1±0.8	9.5±0.9	9.5±1.4
	Spirea	11.0±1.1	10.6±1.0	10.0±1.0
	Rose	7.1±0.9	6.3±1.0	6.5±0.7
	Peavine	8.6±1.6	8.2±1.3	7.1±0.7
Ash	Snowberry	8.2±0.1	7.7±0.5	7.5±0.5
	Spirea	6.0±0.5	6.1±0.6	6.2±0.7
	Rose	7.3±0.5	7.3±0.6	7.0±0.4
	Peavine	8.1±0.9	8.9±0.6	8.2±0.6
Calcium	Snowberry	1.23±0.05	1.24±0.15	1.15±0.11
	Spirea	1.10±0.18	1.04±0.20	1.04±0.11
	Rose	1.51±0.10	1.55±0.10	1.39±0.14
	Peavine	1.75±0.31	1.92±0.21	1.78±0.14
Phosphorus	Snowberry	0.38±0.05	0.30±0.03	0.34±0.08
	Spirea	0.35±0.08	0.33±0.04	0.29±0.05
	Rose	0.38±0.05	0.37±0.03	0.34±0.04
	Peavine	0.18±0.02	0.18±0.02	0.18±0.01

[1]DDM = Digestible dry matter.
[2]ADF = Acid detergent fiber.
[3]ADL = Acid detergent lignin.

energy contents of seven browse species during each season of the year. Two species, Wood's rose and common snowberry, had summer nutritive values similar to those in Table 3. These were the only species common to both studies.

Variation existing in relative proportions of available nutrients among aspen groups (Table 2) is a function of species composition of each class. The relative proportions of each species varied among groups (Severson and Thilenius 1976). Overlapping confidence intervals between groups for the individual species that were tested (Table 3) indicate similarities in nutritive content. This implies that variations in sites, soils, or successional stage do not result in corresponding differences in the nutrient content of a species.

Regardless of nutrient percentage, there will be differences in total amount of that nutrient in an aspen group because of unequal forage production. The altered group, for example, produced greater quantities of most nutrients due to greater forage production, although amounts varied proportionally because of differences in production of each forage class within and between years (Table 4). Relatively less lignin was produced in the altered group because of the low lignin content of grasses as compared to shrubs. The nearly equal proportions of calcium and phosphorus among all groups was also a function of annual production and nutrient percentage of forage classes.

Conclusions and Recommendations

The productive and diverse nature of aspen understory indicates a useful resource for both livestock and many wildlife species. Aspen stands, generally, are dynamic seral stages that will gradually be replaced by conifers, ponderosa pine or white spruce, in the Black Hills (Severson and Thilenius 1976). Aspen stand manage-

Table 4. Maximum ranges of nutrient production, including variations in forage production and nutrient percentages within and between years. Expressed as kg/ha, oven-dried weight.

Nutritive element	Aspen group		
	Young	Mid-aged	Altered
Digestible dry matter	296–553	226–438	346–849
Protein	45.3–87.8	38.6–71.1	49.4–119.1
Acid detergent fiber	182–350	176–310	168–587
Acid detergent lignin	46.2–90.3	45.6–91.8	33.7–97.2
Calcium	6.08–13.92	4.81–9.67	5.47–14.40
Phosphorus	1.24–2.79	1.11–2.10	1.20–2.99

ment is confounded because all stages can be important to specific uses. Cattle, for example, tend to use aspen stands that are relatively free of conifers and have a high proportion of grass in the understory (Kranz and Linder 1973), a description that fits the altered group of this study. During summer white-tailed deer, however, prefer a type similar to the mid-age group, or what Kranz and Linder (1973) described as a mixed aspen-pine type. Ruffed grouse *(Bonasa umbellus)* apparently require very dense, small aspen growth without conifers like the young group, for brood habitat, and older age classes similar to the altered group for winter habitat (Gullion and Svoboda 1972).

Although the nutritive values of species in aspen understory do not appear to differ from those produced in other vegetation types, higher total production results in greater nutrient production per hectare. Aspen understory, like other vegetation types in the western United States, may have some nutrient limitations as related to utilization by ruminants, particularly of protein and phosphorus (or calcium:phosphorus ratios). These limitations can be overcome by selective feeding habits of animals. White-tailed deer, for example, selected plants higher in protein (cream peavine) and higher in phosphorus (common snowberry, shinyleaf spirea, and Wood's rose) than that which was available in the understory as a whole. Management can create the opportunity for grazing animals to utilize this selectivity by insuring that quantity and quality of understory vegetation are balanced. Aspen understory is valuable in this respect because, in addition to being relatively productive, it reportedly contains more species than either mixed aspen-pine or pure pine in the Black Hills (Kranz and Linder 1973). There are equally important differences within the aspen complex; the young aspen group produced the greatest amount (116 to 140 kg/ha) of the four forage species white-tailed deer utilize, the mid-age group an intermediate amount (93 to 97 kg/ha), while the altered group produced the least (66 to 78 kg/ha).

The aspen complex cannot be managed with a single objective or by a single treatment. A variety of seral aspen stages should be created, where it does not already exist, to maximize quantity and quality of the forage and to realize the diversity that is apparently necessary for all uses of this type. Managers can encourage such diversity in large, homogeneous aspen stands by using one or several of these suggested treatments: (1) clearcutting to promote aspen regeneration to create a mosaic of age classes, (2) thinning aspen to promote understory growth, (3) removing invading conifers to promote growth of understory and to slow succession, (4) removing most aspen but retaining all conifers to speed succession, and (5) thinning aspen and conifers to increase understory growth and wood fiber production.

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Vegetation and White-tailed Deer Responses to Herbicide Treatment of a Mesquite Drainage Habitat Type

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Abstract

A honey mesquite drainage habitat (20% of a 1,215-ha study pasture) was aerially sprayed with 1.1 kg/ha of 2,4,5-T + picloram in the spring. Adjacent habitats (blackbrush acacia uplands, creeping mesquite flats, blackbrush acacia-dominated mixed brush, and creeping mesquite-mixed brush) were not sprayed. Discriminant treatment of the honey mesquite drainage habitat did not cause consistent differences in white-tailed deer use of that habitat nor did it change deer use of the pasture containing the sprayed drainage based on average daily fecal accumulation rates for 22.5 months after herbicide application. Lack of differences in deer use between sprayed and unsprayed habitats were attributed to minor impacts of sprays on forb populations during the study period, retention of ample cover screen for deer, and increased abundance of grasses on sprayed areas which presumably reduced use of preferred deer food items by cattle.

The recent surge in economic potential of white-tailed deer *(Odocoileus virginianus),* especially in Texas, has precipitated intense interest in the potential effects of brush control on deer populations. Historically, the primary goal of brush control has been to improve range forage resources or to facilitate their use by livestock (Vallentine 1971). Consequently, most research efforts on interrelationships between brush control and white-tailed deer habitat have been oriented toward threshold levels of woody plant removal relative to their negative impacts on deer numbers.

Broadcast applications of selective herbicides have little immediate effect on screening cover and complete defoliation may require a month or longer. Consequently, aerial spraying of brush apparently has less acute impact on white-tailed deer numbers than do many conventional mechanical brush control methods. Aerial spraying of approximately 80% of mixed brush in alternating strips on areas of 430 to 1,800 ha in south Texas did not cause a net change in white-tailed deer popultions (Beasom and Scifres 1977, Marshall 1978, McKenney 1978, Tanner et al. 1978). These studies, as with most in the past, evaluated treatments which were generally indiscriminant relative to range sites or habitats.

The antithesis of the deer-threshold brush cover relationship is the minimum amount of brush that can be controlled and result in an economically justifiable response to the landowner. This view generates several additional hypotheses which have not been tested. Since vegetation response to brush control is site specific (Scifres 1980), one proposition is that treatment only of range sites with greatest potential for herbaceous forage production (sites which frequently occupy a relatively small area) could increase livestock carrying capacities as much as, or more than, indiscriminant treatment of large portions of a pasture or ranch. However, in much of south and west Texas, the sites with greatest potential for producing herbaceous forages, such as the honey mesquite drainages, are also considered the most important habitat type for white-tailed deer (McMahan and Inglis 1974, Darr and Klebenow 1975). Consequently, managers often have controlled brush on all but these habitats to avoid possible reductions in deer numbers and/or quality. In such cases, resultant brush removal from a pasture may approach 70 to 90%. This research was designed to test the hypothesis that chemical brush control could be applied to the honey mesquite drainages without negatively influencing deer numbers if adjacent habitats were not sprayed.

At the time of the research, the authors were associate professor and professor, Department of Wildlife and Fisheries Sciences; and professor, Department of Range Science, Texas A&M University, College Station, 77843.

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Study Area

This study was conducted on the Camaron Ranch in eastern LaSalle County, about 197 km south of San Antonio, Tex. (Fig. 1). The elevation is approximately 250 m, and the topography is level to gently rolling. Average annual rainfall is about 53 cm, with a peak usually occurring in late spring and another in late summer-early fall.

Study pastures were 1,376 and 1,134 ha and consisted of honey mesquite drainages, blackbrush acacia *(Acacia rigidula)* uplands, creeping mesquite *(Prosopis glandulosa* var. *reptans)* flats, blackbrush acacia-dominated mixed brush, and creeping mesquite-mixed brush as the major habitats (Fig. 1). Woody species which occurred in all habitats were Texas pricklypear *(Opuntia lindheimeri)*, lotebush *(Ziziphus obtusifolia),* knifeleaf condalia *(Condalia spathulata),* guayacan *(Porlieria angustifolia),* spiny hackberry *(Celtis pallida)* and twisted acacia *(Acacia tortuosa).* Whitebrush *(Aloysia lycioides),* Texas paloverde *(Cerdidium texanum),* and retama *(Parkinsonia aculeata)* occurred primarily in the honey mesquite drainages. Guajillo *(Acacia berlandieri),* ceniza *(Leucophyllum frutescens),* and bumelia *(Bumelia celastrina)* occurred primarily on the blackbrush acacia uplands. Plant nomenclature follows Gould (1975).

Range condition was generally poor to low fair at initiation of the study. The pastures were grazed yearlong at 1 AU/8 ha as a part of a cow-calf operation. The deer density in the general area was reportedly 10 to 11 ha/animal (McMahan and Inglis 1974).

Methods

Approximately 70% (243 ha) of the mesquite drainage type in the larger pasture (about 20% of the total land area) was aerially sprayed on May 27, 1977 with 1.1 kg/ha (total herbicide) of 2,4,5-T [(2,4,5-trichlorophenoxy)acetic acid] + picloram (4-amino-3,5,6-tricholorpicolinic acid) as a 1:1 commercial mixture in 37 L/ha of a diesel oil L/ha of a diesel oil:water (1:3) emulsion. During the first week of June 1977, canopy cover by woody species was recorded at 100, equally spaced points down the center of the treated and untreated drainages using the point-centered quarter method (Cottam and Curtis 1956). Canopy diam of the nearest woody plant in each quadrat was converted to canopy area, and average area per

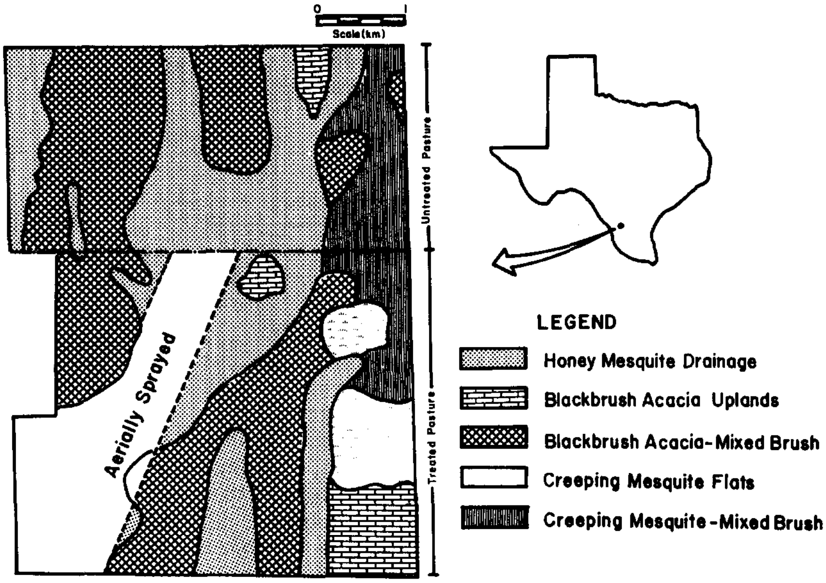

Fig. 1. *Position of honey mesquite drainage sprayed with 1.1 kg/ha of 2,4,5-T + picloram (1:1) in relation to other habitats near Cotulla, Texas.*

plant was multiplied by the plant density for the habitat to derive canopy cover.

Thirty grazing exclosures, 3.7 cm in circumference and 1.4 m tall and constructed of wire mesh with 10-cm openings, were equidistantly spaced along a line through the long axis of the sprayed area. Thirty such exclosures were also established in untreated mesquite drainage within 100 m of the edge of the treated area and on lines parallel to those in the sprayed drainage. Standing crops of herbaceous vegetation were harvested at 4, 15, and 27 months after herbicide application by clipping a 0.25-m^2 area to a 2.5 cm stubble height from the center of each exclosure. Based on random selection of one of the cardinal directions, a 0.25-m^2 unprotected area 1 m from each exclosure was also harvested. The exclosures were then relocated, based on random selection of the cardinal directions, 10 m from the original location. Grazing activities of livestock disturbed some of the exclosures so that sample numbers ranged from 19 to 29 per treatment among sampling times. Herbage was separated into grasses and forbs, dried at 100°C for 48 hours, and weighed.

Relative density indices of forbs were determined by visual assessment at approximately 6-week intervals from April 1977 through April 1979 on circular 30-m^2 plots (72 in the sprayed area, 234 in the untreated portion of the sprayed pasture, and 222 in an adjacent untreated pasture). Plot locations were stratified by habitat but sampling points were randomly placed within the brush stands. Arbitrary abundance classes (plants/plot were *0* = none, *1* = 1-5, 2 = 6-50, *3* = 51-500, *4* = 501-5,000, and *5* = over 5,000. Treatment effects were evaluated by analysis of variance across sampling periods.

Canopy cover reductions of woody plants by species were estimated in September 1977, May 1978, and July 1979 in ten, 15-m-wide by 156-m-long sampling areas which were equidistantly spaced through the long axes of the treated and untreated honey mesquite drainages. Percentage canopy reductions by species between treatments within years were compared by *t*-test ($P \leq .05$).

Relative deer abundance between pastures and between treatments of habitat types within pastures was evaluated by fecal pellet group accumulation on the vegetation plots. The initial evaluation (1 month pretreatment) represented all fecal groups that had accumulated prior to the study and could be used only as a relative indicator of previous deer use among habitats. Since fecal groups were removed after each assessment, subsequent data were reported as average number of groups accumulated per plot per day. The evaluation periods coincided with assessments of forb stands on the plots. McMahan (1973) reported deer pellet group accumulation data on plots in a nearby area to be distributed as a negative binomial. Therefore, the raw data were transformed by the inverse hyperbolic sin (C.E. Gates, pers. commun.) by the formula $sin^{-1}\sqrt{y + 1/2} = ln(\sqrt{y + 1/2} + \sqrt{y + 3/2})$ where y = observed count and ln = $\log_e$ prior to conducting analysis of variance. Means of transformed data were separated by Duncan's multiple range test (Steel and Torrie 1960).

Results

Woody plant canopy cover averaged 46% at the time of herbicide application to the honey mesquite drainage. Proportions of the woody cover by species were honey mesquite, 42%; pricklypear, 16%; blackbrush acacia, 15%; spiny hackberry, 11%; and twisted acacia, 8%. Lotebush condalia, guayacan, knifeleaf condalia, and Texas paloverde each accounted for less than 3% of the woody plant canopy cover.

Average canopy reduction of woody plants and percentage of plants completely defoliated and not sprouting from stem bases (plants killed) varied widely among species. Average canopy reductions of honey mesquite, spiny hackberry and Texas paloverde ranged from 90 to 100% throughout the study period (Table 1). The responses of the three former species are consistent with previous research results (Scifres et al. 1977) but less is known concerning

Table 1. Average percentage estimated canopy reduction (CR) of woody plants and percentage of the population completely defoliated and not sprouting from stem bases (TD) at various times after aerially spraying a honey mesquite drainage habitat with 1.1 kg/ha of 2,4,5-T + picloram on May 22, 1977, on the South Texas Plains.

	Months after herbicide application[1]					
	4		12		26	
Woody species	CR	TD	CR	TD	CR	TD
Honey mesquite	95*	90*	98*	80*	93*	82*
Twisted acacia	92*	33*	82*	26*	74*	14*
Blackbrush acacia	70*	40*	90*	30*	94*	32*
Lotebush	75*	0	12	0	23*	0
Guayacan	0	0	0	0	0	0
Knifeleaf condalia	0	0	12	0	0	0
Spiny hackberry	95*	0	100*	48*	92*	82*
Texas paloverde	90*	85*	100*	100*	100*	98*
Texas pricklypear	0	0	82*	0	89*	78*

[1] Asterisked means indicted significant reduction ($P \leq .05$) compared to untreated stands based on *t*-test.

the response of Texas paloverde to 2,4,5-T/picloram mixture. Blackbrush acacia and Texas pricklypear responded more slowly than did honey mesquite to the aerial spray, but average reduction in live aerial parts exceeded 80% by 12 and 26 months after herbicide application. Canopy reduction of twisted acacia averaged 92% at 4 months after treatment but the species had recovered somewhat during the second and third growing season. Although initial canopy reduction averaged 75%, lotebush was only partially controlled by the treatment; and gauyacan and knifeleaf condalia were essentially unaffected.

Based on percentage of the population completely defoliated and not sprouting from the bases, reduction of live honey mesquite at 26 months after spraying in this study (73%, Table 1) was greater than the long-term average (42%, Scifres 1973). Likewise, percentage of spiny hackberry plants killed was higher than reported in previous research (Scifres et al. 1977). Thus, relative to response of woody plants, the herbicide treatment was deemed highly effective.

Annual rainfall was 38.5 cm (73% of the long-term average) during 1977, 65.3 cm in 1978 (124% of the long-term average), and was 34.3 cm in 1979. Standing crops of grasses were increased ($P \leq 0.05$) 3.5 to 9.7 fold on the aerially sprayed honey mesquite drainage compared to those from the similar but untreated habitat, regardless of evaluation time (Table 2). Rainfall during the period from herbicide application to first harvest of grasses was 22 cm. The greatest difference in grass standing crop between sprayed and unsprayed drainages occurred in late July 1979, 15 months after initiation of the study (Table 2). During the 60-day period preceding this harvest, approximately 24 cm of rainfall were received.

Average forb standing crop was reduced ($P \leq 0.05$) on the sprayed drainage, compared to that on the unsprayed drainages during the growing season of herbicide application (Table 2). Forb standing crops were low, regardless of treatment, the second and third growing seasons of study.

Average forb density indices are presented so that comparisons of (1) sprayed with untreated honey mesquite drainages, (2) sprayed drainage with untreated uplands in the pasture containing the sprayed drainage, and (3) overall average forb abundance of whole pastures, whether partially sprayed or untreated, are possible (Table 3). Forb densities on the sprayed and untreated drainages were roughly equivalent or were greater on sprayed drainages except during the growing season of herbicide application. During the period from spraying to 4.75 months posttreatment, forb abundance on the sprayed drainage was reduced compared to those on untreated drainages (Table 3), as were standing crop of forbs (Table 2). However, the tendency from 9 to 22.5 months after spraying was for forbs to be more abundant on the sprayed than on the untreated drainage (Table 3). Comparison of average forb indices between the sprayed honey mesquite drainage and the upland habitat type paralleled differences between sprayed and untreated honey mesquite drainages. Comparison between whole pastures indicated no appreciable pasturewide effect of spraying on average forb abundance.

The pellet group data provided the same 3 types of comparisons as did the forb density indices. The high intensity use of drainages relative to adjacent untreated uplands demonstrates a typical pattern of habitat selection by white-tailed deer on the South Texas Plains. This use pattern was not changed by aerial spraying with 2,4,5-T + picloram. Comparison of fecal accumulation rates between sprayed and untreated honey mesquite drainages indicates no early negative response of white-tailed-deer to the brush treatment with the possible exception of reduced use of treated drainages at 6 to 8 months after treatment (Table 4). The tendency after 1 year was for pellet group accumulation rates to be greater on the sprayed than on the untreated drainage. Pasturewide comparisons suggest that deer may have reduced their relative use of the pasture containing the sprayed drainage from 5 to 10 months after herbicide application. However, overall difference in pasture use by deer in response to spraying of the honey mesquite drainage was minor. Any expectation that deer would be driven out of the sprayed honey mesquite drainage, either acutely or chronically,

Table 2. Oven-dry standing crop of grasses and forbs on honey mesquite drainage habitat at various times after aerially spraying with 1.1 kg/ha of 2,4,5-T + picloram on May 22, 1977, compared to adjacent untreated habitat on the South Texas Plains.

Months post treatment	Standing crop (kg/ha)[1]			
	Grasses		Forbs	
	Sprayed	Untreated	Sprayed	Untreated
4	1,418* ± 134	403 ± 67	100* ± 6	203 ± 20
15	3,086* ± 201	319 ± 49	11 ± 8	6 ± 3
27	1,131* ± 111	292 ± 81	T[2]	T

[1]Means marked by asterisk are significantly different ($P \leq .05$) from those of untreated area at the same sampling time.
[2]T = trace, less than 5 kg/ha.

Table 3. Average forb density indices on: (1) a honey mesquite drainage habitat which was aerially sprayed on May 22, 1977, with 1.1 kg/ha of 2,4,5-T + picloram, (2) an untreated habitat adjacent to the mesquite drainage, (3) an untreated mesquite drainage in an adjacent pasture, (4) the entire pasture containing the sprayed drainage, and (5) an entire, adjacent untreated pasture.

Months post treatment	Forb density index				
	Mesquite drainage		Untreated habitat of pasture containing sprayed drainage	Entire pasture which contained sprayed drainage	Entire pasture, untreated
	Untreated	Sprayed			
-1.00	2.6 a[1]	2.4 a	2.9 b	2.8 ab	2.5 a
0.25	2.2 a	2.4 a	2.4 a	2.4 a	2.3 a
1.75	2.0 b	1.6 a	2.1 b	2.0 b	2.0 b
3.25	1.6 b	0.8 a	1.3 b	1.3 ab	1.5 b
4.75	1.7 c	1.0 a	1.2 b	1.1 a	1.4 bc
6.25	1.3 a	1.3 a	1.2 a	1.3 a	1.5 a
7.50	0.8 a	0.9	0.9 a	0.9 a	0.8 a
9.00	1.5 b	2.8 c	1.1 a	1.5 b	1.7 b
10.25	1.0 b	1.9 c	0.8 ab	1.1 b	0.7 a
11.75	1.6 b	1.7 b	1.2 a	1.5 ab	1.8 b
13.00	1.7 a	2.0 a	1.9 a	2.0 a	2.0 a
14.75	2.0 a	1.9 a	1.8 a	1.9 a	2.2 a
16.50	1.3 a	1.7 a	1.6 a	1.7 a	1.4 a
19.50	1.3 b	1.5 b	1.0 a	1.1 a	1.2 ab
21.25	1.2 ab	1.9 c	1.4 ab	1.5 b	1.1 a
22.50	1.6 a	2.2 c	1.8 ab	1.9 b	1.8 ab

[1]Means within a row, followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

was not demonstrated by these data. Rates of pellet group accumulation were higher on the adjacent pasture than on the pasture containing the sprayed drainage in only 4 of 16 sampling periods. Reductions in rate of pellet group accumulation in the treated pasture were probably attributable to inherent differences in its carrying capacity compared to the untreated pasture.

Discussion

Results from aerially spraying the mesquite drainage habitat in this study differ from those of Darr and Klebenow (1975) who reported that chaining of bottomlands in the Rolling Plains of Texas significantly reduced white-tailed deer numbers for several years, and that herbicides caused a negative resonse for 3 to 5 years. Obviously, chaining drastically reduces woody plants available for deer cover in bottomlands. However, relative impacts on deer use from one location to another doubtless result from the abundance and structure of available, untreated woody cover. Similarly, differing impacts attributable to herbicide use may result from differences in cover screen between the 2 situations after defoliation of the woody plants. Since an insignificant reduction in cover screen from 0 to 0.9 m (deer height) is noted after herbicide treatment of mesquite brushland (Tanner 1976), any reduction in cover screen in our study may have been mitigated by a general increase in available food supply.

The variable efficacy of herbicides because of differences among sprayed sites relative to soil water availability and soil type, age and species of woody plants, and weather factors has been documented (Fisher et al. 1953, Dahl et al. 1971, Scifres 1980). However, it is generally true that economically-acceptable herbicide treatments result in at least partially killing woody plant stands (Bovey et al. 1968; Meyer and Bovey 1973; Whitson and Scifres 1980). Frequently, resprouting from defoliated woody plants increases the amount and/or availability of browse (Krefting and Hansen 1969) and new sprouts are preferred to mature branches by white-tailed deer (Powell and Box 1966). Resprouting browse plants generally also contain higher levels of protein, phosphorus, and total digestible nutrients than mature or decadent ones (Dietz 1972).

Although an indirect influence, the general increase in herbaceous vegetation probably also influenced food availability for white-tailed deer in this study. McMahan and Inglis (1974) concluded that forbs were the food items that most attracted deer utilization to range sites, given an adequate cover screen. The 3 to 10-fold increase in grass abundance on the sprayed honey mesquite drainage should have improved conditions for deer by reducing cattle utilization of forbs and browse. Other studies with herbicides have reported an initial reduction in forbs followed by a return to pretreatment levels after several months (Beasom and Scifres 1977, Scifres et al. 1977), but a general increase apparently is uncommon.

From a management viewpoint, results herein suggest that aerially spraying honey mesquite drainage habitats in south Texas is a useful tool for increasing herbaceous forage for livestock. Moreover, such treatments when applied to about 20% of the land area in a pasture and leaving adjacent habitats undisturbed have negligible impact on white-tailed deer use. Thus, the hypothesis that preferred habitats such as the honey mesquite drainage can be aerially sprayed for brush management without a negative response by deer, if adjacent habitats are left undisturbed, cannot be rejected based on results of this study. Further, site-specific treatment appears advantageous in that only sites of greatest response potential are treated, thus reducing overall brush management costs, by exempting sites of lower forage production potential. However, it is suggested that site selection must be conducted on a case-by-case basis with cognizance of the relative importance of adjacent habitats for white-tailed-deer.

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	Avg. pellet groups/plot day (X 100)				
Months post treatment	Mesquite drainage: Untreated	Mesquite drainage: Sprayed	Untreated habitat of pasture containing sprayed drainage	Entire pasture which contained sprayed drainage	Adjacent entire pasture, untreated
-1.00[1]	2.2 c[2]	5.2 d	0.8 a	1.7 bc	1.3 ab
0.25	0.4 a	1.2 a	0.5 a	0.7 a	1.0 a
1.75	0.3 a	0.3 a	0.7 b	0.6 b	0.5 b
3.25	1.0 bc	1.2 c	0.3 a	0.5 a	0.7 ab
4.75	0.5 b	0.5 b	0.2 a	0.2 a	1.1 c
6.25	2.1 b	1.4 a	0.4 a	0.6 a	1.7 ab
7.50	2.0 b	1.1 a	1.0 a	1.0 a	2.4 b
9.00	2.2 b	1.7 b	0.8 a	1.0 a	1.6 b
10.25	1.1 ab	1.7 b	0.6 a	0.9 a	0.7 a
11.75	1.0 a	3.4 b	1.1 a	1.5 a	1.0 a
13.00	1.3 a	3.1 b	0.8 a	1.3 a	1.4 a
14.75	0.6 c	0.0 a	0.1 b	0.1 b	0.2 b
16.50	0.2 a	0.5 b	0.3 a	0.3 a	0.3 a
19.50	0.5 a	1.2 b	0.4 a	0.6 a	0.3 a
21.25	0.8 c	0.4 b	0.2 a	0.3 ab	0.8 c
22.50	0.8 ab	1.0 b	0.5 a	0.6 ab	0.8 ab
Sample units	54	74	222	296	222

[1]Pretreatment values are total pellet groups accumulated prior to sample date with no regard for time so they do not represent deposition rates.
[2]Means in row followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

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High and Low Sodium Biotypes of Fourwing Saltbush: Their Responses to Sodium and Potassium in Retorted Oil Shale

STEVEN G. RICHARDSON

Abstract

Two of 5 populations of fourwing saltbush *(Atriplex canescens)* examined in eastern Utah did not accumulate appreciable amounts of sodium in leaf tissue while 3 populations did accumulate sodium in leaves. The characteristics of sodium accumulation and nonaccumulation were exhibited in these populations when leaf tissue was collected from plants growing in the field or from plants grown in saline retorted oil shale in 2 greenhouse pot experiments. The plants that were low in sodium were higher in potassium but lower in total sodium plus potassium. Growth of plants from the low sodium populations was enhanced by addition of potassium to the retorted oil shale but potassium addition had no effect on growth of the high sodium plants. Top growth of the high sodium plants was greater than growth of the low sodium plants on retorted oil shale.

A common characteristic of desert halophyte species of the Chenopodiaceae family is the accumulation of large concentrations of mineral ions in leaf tissues (Wallace et al. 1973, Wiebe and Walter 1972). Accumulation of salts in leaves may affect palatability (Wallace et al. 1973) and soil salinity (Sharma and Tongway 1973). The various genera and species may differ in the amounts and even the kinds of ions accumulated. For example, greasewood *(Sarcobatus vermiculatus)* had high concentrations of sodium in leaves while spiny hopsage *(Grayia spinosa)* in the same plant community had high potassium concentrations in leaves but only very low sodium concentrations (Rickard 1965). This paper reports the identification of sodium-accumulating and non-sodium-accumulating populations of fourwing saltbush *(Atriplex canescens)*. The paper also compares sodium and potassium concentrations in leaves as affected by Na and K in the growth medium and growth characteristics of the two types when grown in saline retorted oil shale with and without added potassium.

Methods

Field Survey

Leaves were collected from a total of 23 fourwing saltbush plants in 5 populations (groups of plants several miles apart) in the vicinity of Bonanza, Uinta County, Utah, on July 26, 1978. The leaves were oven-dried at 80° C for 24 hrs., ground, and extracted with deionized water. The extracts were analyzed for sodium (Na) and potassium (K) by atomic absorption spectrophotometery. Stem cuttings were collected from each of the 23 plants and propagated in the greenhouse by the methods of Richardson et al. (1979) for use in subsequent studies.

Greenhouse Experiments

The first of 2 greenhouse experiments was designed to verify the existence of high and low sodium biotypes as suggested from the field survey and to compare the effects of different salinity levels on concentrations of Na and K in leaves.

Paraho retorted oil shale from Anvil Points, Colo., was leached with distilled water to reduce the salinity to an ECe (electrical conductivity of a saturation extract) value of 4.1 mmho/cm. The leached Paraho shale contained 0.2 meq (milliequivalents) Na/100g and 0.1 meq K/100 g. Eighty 24 oz. cottage cheese cartons were each filled with 700 g oven-dried, leached shale that had been sieved through a 6.35-mm mesh screen. Half the pots were treated with 100 ml of sodium sulfate solution, with an EC of 42 mmho/cm, which brought the ECe of the retorted shale to 18.6 mmho/cm. All pots were fertilized with 100 ppm N, 44 ppm P, and 83 ppm K by weight. Four replicates of 5 low sodium and 5 high sodium plants, chosen at random, were planted as rooted cuttings into the low salinity (ECe = 4.1 mmho/cm) and the high salinity (ECe = 18.6 mmho/cm) retorted shale. Soil moisture was raised to 20% by weight and maintained at that level by daily weighed additions of distilled water. Following 60 days of growth in a greenhouse, leaves were harvested, dried, ground and analyzed for soluble Na and K with an atomic absorption spectrophotometer.

In the second experiment, the effects of K added to retorted oil shale on leaf Na and K concentrations and on plant growth were examined. Sixty-four 24 oz. size cottage cheese cartons were each filled with 700 g Union B retorted Utah oil shale previously sieved through a 6.35 mm mesh screen. The ECe of the retorted shale was 8.0 mmho/cm. The water soluble sodium (Na) concentration was 2.0 meq/100 g, and the water soluble potassium (K) concentration was 0.1 meq/100 g. Each pot of retorted shale was fertilized with 103 ppm N (as calcium nitrate) and 34 ppm P (as sodium phosphate). Half the pots were treated with 100 ppm K (as potassium sulfate).

Four high sodium plants and 4 low sodium plants were selected at random from the 23 plants previously collected from the field near Bonanza, Utah. Rooted cuttings were planted in the pots of shale and the shale was watered to 20% moisture by weight, which was maintained by daily weighing and watering with distilled water. The experimental design was a randomized block in factorial arrangement with 2 plant types, 4 plants per type, 2 potassium concentrations, and 4 replicates. After 60 days of growth in a greenhouse, plant tops were harvested, dried at 80° C for 24 hours, and weighed. Leaves were separated, ground, extracted with distilled water, and analyzed for Na and K by atomic absorption spectrophotometry.

Results

In the field survey 3 populations had leaf sodium concentrations greater than 100 mmole/100 g, while 2 populations had less than 10 mmole Na/100 g leaf dry matter (Table 1). Potassium concentrations in leaves were high when sodium concentrations were low. The sum of Na plus K concentrations in leaves was higher in the populations where Na in leaves was also greater.

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Table 1. Sodium and potassium concentrations in fourwing saltbush leaves collected from 5 populations in eastern Utah.

Associated vegetation	Population	Number of plants sampled	Soluble ions in oven-dry leaves (mmole/100 g)[1]		
			Na	K	Na+K
Sagebrush, greasewood, shadscale	A	6	103 ± 18	53 ± 7	156 ± 13
Sagebrush, greasewood	B	3	141 ± 7	28 ± 1	169 ± 7
Sagebrush, shadscale	C	6	136 ± 19	34 ± 3	170 ± 13
Shadscale, grass	D	4	4 ± 1	71 ± 10	75 ± 10
Sagebrush, juniper, greasewood	E	4	9 ± 5	81 ± 4	90 ± 3

[1]Mean values ± standard error.

When the plants were grown on Paraho retorted oil shale in the greenhouse the same pattern of sodium and potassium concentrations in leaves existed as was found in the field survey (Table 2). The plants that were low in leaf sodium in the field remained lower in sodium, higher in potassium and lower in Na plus K than the plants that had high leaf sodium in the field. An increase in sodium sulfate salinity of the retorted oil shale resulted in increased Na plus K concentrations in leaves, but the increase was greater in the high sodium plants. The high sodium plants responded to higher salinity with increased concentrations of Na in leaves while low sodium plants responded primarily with increased K concentration in leaves.

Addition of K to the Union B retorted shale caused a greater increase in leaf K in the low Na plants than in the high Na plants (Table 3). There was a slight decrease in leaf Na with the addition of K to the shale. There were also differences in Na and K contents of leaves among plants within each biotype. This was also observed in the other experiment and in the field survey.

Top growth of the high sodium plants was greater than top growth of the low sodium plants (Table 4). Addition of K to the retorted shale caused increased growth of the low sodium plants but not the high sodium plants. The analysis of variance (not shown) also revealed that plant differences within each plant type were significant (.01 level). Although K had a significant effect on the low sodium plant type, the overall effect when data for low sodium and high sodium plants were combined was not significant at the .05 level. None of the interactions were significant.

Discussion

The data show that distinct biotypes of fourwing saltbush exist with regard to sodium accumulation. Interspecific crosses in nature among various saltbush species are not uncommon (Blauer et al. 1976, Stutz and Sanderson 1977). It is possible that the high sodium biotype of fourwing saltbush may possess genes for sodium accumulation derived from another *Atriplex* species that absorbs large amounts of sodium. If this were true, greater growth of the high sodium biotype than the low sodium biotype might be due to hybrid vigor. Fourwing saltbush is not the only species of saltbush that may tend to exclude sodium and absorb large amounts of potassium. Breckle (1974) also found that *A. falcata* growing in very saline soils just north of the Great Salt Lake in Utah had this same tendency for sodium exclusion and potassium accumulation. Some differences in Na and K accumulation among individual plants within each fourwing saltbush biotype were also noted in this study. Inheritance of the traits could be complex, involving multiple alleles rather than simple dominant and recessive genes. Thus a broad spectrum of degrees of sodium accumulation or nonaccumulation could be possible.

Wallace et al. (1973) and Wallace and Romney (1972) reported much lower sodium levels in fourwing saltbush leaves than in leaves of other saltbush species. Wallace et al. (1973) suggested that the low sodium content of fourwing saltbush relative to many other saltbush species is one reason for its high forage value. If this is true, then forage value (possibly palatability or oxalate content) would likely differ between the high sodium and low sodium biotypes of fourwing saltbush.

The lack of correlation between ash content of fourwing saltbush and soil salinity in a study by Welch (1977) may be due to the existence of sodium-accumulating and sodium-excluding biotypes. Sodium compounds are usually the primary contributors to soil salinity, but soil potassium is probably more closely related to mineral or ash content of the low sodium biotype than is soil sodium.

The high sodium biotype of fourwing saltbush apparently has a lower potassium requirements than the low sodium biotype. The lower requirement for K in the high sodium biotype may be due to an ability to use Na as a partial substitute for K. The apparent partial substitution of sodium for potassium in plant nutrition has also been observed in other species by other researchers (e.g., Hylton et al. 1967, Harmer and Benne 1945, Dow and James 1970, Ulrich 1961).

Accumulation of salts (particularly sodium salts) in leaves with subsequent leaf fall causes an increase in surface soil salinity and sodicity beneath saltbushes and other halophytes (Sharma and Tongway 1973, Rickard and Keough 1968, Eckert and Kinsinger 1960). Such salt accumulation at the soil surface may adversely affect establishment of herbaceous understory species and thus may affect plant community development. Rickard et al. (1973) found that soil collected beneath spiny hopsage, which accumulates potassium in leaves, was more favorable to the growth of cheatgrass *(Bromus tectorum)* than was soil beneath greasewood, which accumulates sodium in leaves. Similarly, the low sodium fourwing saltbush biotype may provide a more favorable environ-

Table 2. Sodium and potassium concentrations in leaves of low sodium and high sodium biotypes of fourwing saltbush grown in leached Paraho retorted oil shale and leached shale plus sodium sulfate.

Biotype	Shale ECe[1] (mmho/cm)	Mineral concentrations (mmole/100g)[2]		
		Na	K	Na + K
Low sodium	4.1	2 ± 0.2	98 ± 5.7	100 ± 5.5
	18.6	13 ± 1.9	139 ± 4.7	152 ± 4.4
High sodium	4.1	50 ± 8.9	71 ± 3.7	120 ± 11.4
	18.6	128 ± 14.7	68 ± 5.5	196 ± 18.7

[1]ECe values were 4.1 mmho/cm for the leached shale and 18.6 mmho/cm for leached shale plus sodium sulfate.
[2]Data are mean values ± standard error.

Table 3. Sodium and potassium concentrations (mmole/100 g)[1] in leaves of high sodium and low sodium biotypes of fourwing saltbush grown on Union B retorted oil shale with and without added potassium.

Biotype	K added (ppm)	Na	K	Na + K
Low sodium	0	12 ± 4.9	115 ± 10.1	127 ± 8.6
	100	11 ± 4.5	133 ± 6.7	143 ± 6.3
High sodium	0	70 ± 4.5	92 ± 7.4	162 ± 4.6
	100	58 ± 4.7	107 ± 10.3	165 ± 7.3

[1]Mean values of four replicates ± standard error.

Table 4. Top growth (g/pot)[1] of high sodium and low sodium biotypes of fourwing saltbush as affected by potassium addition to Union B retorted oil shale.

K added (ppm)		Low sodium biotype	High sodium biotype
0		2.81*	4.11
100		3.24*	4.16
	$\bar{X}$	3.03**	4.14**

[1]Mean values of 4 replicates
*Significantly different at .05 level
**Significantly different at .01 level

ment for understory species than the high sodium fourwing saltbush biotype would. This could be especially important where roots of deep-rooted saltbush penetrate a soil covering and come into contact with saline retorted oil shale.

The sodium accumulating and sodium excluding biotypes of fourwing saltbush differed in production, potassium requirement, and sodium and potassium concentrations in leaves. There is reason to believe that the biotypes may also differ in salt tolerance, palatabilty, and effects on soil properties. Thus existence of the two biotypes may have implications for disturbed land rehabilitation and management of salt desert shrub rangelands. Further research is needed to ascertain the extent of sodium accumulation and nonaccumulation (Na exclusion) in fourwing saltbush and other saltbush species, to define the inheritance patterns of the characteristics, and to determine the ecological and management significance of this physiological phenomenon.

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TECHNICAL NOTES

Sheep Producers' Reasons for Ceasing Farm-Flock Operations in Kansas

ROBERT J. ROBEL AND ROBERT L. MEDUNA

Abstract

During a study of losses of sheep to canine predators in south-central Kansas, we surveyed sheep producers no longer in business to determine why they ceased operations. Advancing age and/or poor health and predator problems were the reasons most producers listed for quitting business.

This study was a small portion of a larger project (Robel et al. 1981), that evaluated the efficacy of several husbandry methods in reducing sheep losses to coyotes *(Canis latrans)* and dogs. Descriptions of the farm-flock sheep industry and topography of the study area are presented in Robel et al. (1981). Kansas ranked 14th in sheep production in the United States during 1975-1976 when this study was conducted but the number of sheep produced in Kansas had declined during the previous 15 years (Kansas State Board of Agriculture 1976).

Methods

All members on the Kansas Sheep Association mailing list in a 9-county area of south-central Kansas were contacted by mail and requested to participate in our sheep husbandry study. Of those contacted, 225 reported that they were no longer in the sheep production business. Questionnaires were mailed to those 225 former sheep producers who ceased operations between 1973 and 1975. They were provided a list of causes for ceasing operations and asked to check the primary reason. They also were asked to list other contributing factors. Copies of survey forms and cover letters are in Meduna (1977). Additionally, 12 sheep producers who were cooperating in our 15-month sheep husbandry study sold their operations and the reasons for their doing so were determined.

Results and Discussion

Of the 225 questionnaires sent to former sheep producers in the study area, 122 (54.2%) were completed and returned. Advancing years and/or poor health and problems with predators were the two most commonly listed reasons they gave for ceasing sheep operations (Table 1). Advancing age and/or poor health was listed as the primary cause by 36 (39.1%) of the 92 producers listing a primary cause for ceasing operations, and as a secondary cause by 19 (21.1%) of the 90 former sheep producers who indicated contributing causes. Predator problems were listed as the primary cause by 26 (28.3%), and a secondary cause by 17 (18.9%). Switching to other farm operations and unprofitability of sheep production combined were listed as primary reasons for going out of the sheep business by 15 (16.3%) former producers, and as contributing causes by 28 (31.1%). Other reasons for quitting were listed much less frequently.

Table 1. Reasons given by 122 former sheep producers in south-central Kansas for terminating farm-flock sheep business, 1975-76.

Reason	Primary cause[1]	Contributing factors
Advancing age and/or poor health	36	19
Problems with predators	26	17
Switched to other agricultural production	9	16
Unprofitability of sheep operation	6	12
Other employment	3	4
Difficulty finding shearers	1	6
Labor requirements too high	0	4
Marketing problems	0	3
Other	11	9

[1]Only 92 sheep producers listed a primary reason for terminating their operation; contributing factors were cited 90 times.

Of the 12 sheep producers who sold their sheep operations during our sheep husbandry study, 6 did so because of advancing age, 2 because of labor problems, 2 because of economic problems, 1 because of reproductive problems in his sheep flock, and 1 because of predator problems.

Results from our survey of reasons for farm-flock sheep producers going out of business were similar to results for range operations in the West. Gee and Magleby (1976) noted that few young persons were entering sheep production and that about 10% of the current producers probably would retire within the decade. Gee et al. (1977) predicted a continued decline in sheep producers barring a substantial increase in persons entering sheep production.

Responses provided by former sheep producers in our Kansas study indicated that predators were considered an important reason for going out of business. Predators often have been implicated in the decline of the sheep industry (Early et al. 1974, Johnson and Gartner 1975, Pearson 1975, Gee and Magleby 1976). Our data support such claims, i.e., 26 of 122 (21.3%) of the producers listed predator problems as the primary reason for quitting the sheep business. That figure may reinforce our finding that 80% of all sheep losses were suffered by 22% of the sheep producers (Robel et al. 1981). Although the 1% average annual loss of sheep to predators in Kansas (Robel et al. 1981) is extremely low, averages often are misleading. Higher than average losses experienced by some sheep producers may cause them to cease operations or pursue other agricultural opportunities. A business-mined sheep producer

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faced with fairly low but constant losses is likely to liquidate the sheep flock if economic conditions indicate that alternative husbandry methods are not economically feasible.

Several former producers terminated their sheep operations in favor of other livestock (cattle or swine) or cash crops like wheat, soybeans, and/or milo. Such changes are rather common in Kansas and reflect changing economic forces in the agricultural sector.

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Comparison of Micro- and Macro- digestion Methods for Fiber Analysis

J.L. HOLECHEK AND M. VAVRA

Abstract

Micro-methods for analyses of neutral detergent fiber (NDF), acid detergent fiber (ADF), and permanganate lignin were compared to the macro-methods of Van Soest (1963) and Van Soest and Wine (1967, 1968). Differences between the two methods were small although the micro-methods gave better precision for ADF while the macro-method gave better precision NDF and lignin. Time and reagents needed for analysis were reduced over 60% with the micro-digestion methods.

In recent years the methods of Van Soest (1963) and Van Soest and Wine (1967, 1968) have become standards for analysis of fiber in forages and ruminant diets. Problems associated with these methods include time required for analysis and investment in equipment. The number of samples that can be digested is severely limited by the number of digestion and refluxing units. Waldern (1971) modified the macro-digestion procedures of Van Soest (1963) and Van Soest and Wine (1967, 1968) into micro-techniques that require less time, fewer chemicals and less equipment. However, he only evaluated the effectiveness of the micro-procedure with forage samples containing low neutral detergent fiber (<56%) and acid detergent lignin (<7%). The objectives of this study were to compare neutral detergent fiber, acid detergent fiber, and permanganate lignin values determined by a modification of the micro-digestion techniques of Waldern (1971) with the macro-digestion techniques of Van Soest (1963) and Van Soest and Wine (1967, 1968) using diet samples from esophageally fistulated cattle.

Methods and Materials

Diet samples were collected in 1976 on mountain range in northeastern Oregon. The botanical composition of these samples was determined using the procedures of Sparks and Malechek (1968). Five diet samples were chosen that represented different forage classes and seasons. In late spring (June 20–July 18) on northeastern Oregon mountain ranges forages are immature and highly digestible. Grasses and forbs are the major diet constituents (Holechek 1980). In late summer (August 15–September 14) diet shifts occur where availability or alternate forages allow. Cattle often consume shrubs in late summer and fall (September 14–October 12). Therefore, diets analyzed were high grass and high forb, late spring; high grass and high shrub, late summer; and high browse, fall. "High" refers to the diet constituents that comprised 40% or more of the total diet. Fifteen sub-samples from each of the 5 selected esophageal fistula samples were digested by the micro-digestion (Waldern 1971) and standard Van Soest (1963) and Van Soest and Wine (1967 1968) digestion procedures. Differences between the two methods were tested using a paired t-test according to Steel and Torrie (1960).

Authors, at the time of the research, were graduate assistant and professor of range nutrition, Oregon State University, Eastern Oregon Agricultural Research Center, Union 97883. J.L. Holechek is currently assistant professor of range science, Department of Animal and Range Sciences, New Mexico State University, Las Cruces 88003.

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Procedure

The procedures of Van Soest (1963) were used as the standard for neutral detergent fiber (NDF) analysis. The procedures of Van Soest (1963) and Wine (1967, 1968) were used as the standards for acid detergent fiber (ADF) and permanganate lignin analyses. Reagents used were those outlined by Van Soest (1963) for NDF and Van Soest and Wine (1967, 1968) for ADF and lignin. The micro-digestion technique had some apparatus and procedural differences from that used by Waldern (1971), and is described a follows:

Apparatus

1) A cylindrical aluminum block with 28 holes.
   a) Block dimensions: 20.32 cm in diameter; 7.62 cm deep.
   b) Hole dimensions: 2.54 cm in diameter, 5.06 cm deep.
2) Chromalox 660 watt hevi-duty heater with rheostat.
3) Marbles, 25.4 mm in diameter to serve as condensers.
4) 25 × 225 mm test tubes.
5) Sintered glass crucibles as described by Van Soest (1963).
6) Vacuum pump for filtration.

NDF Procedure

1) Weight .35g air dried sample which has been ground through a #40 sieve into a test tube.
2) Add 35 ml of NDF solution.
3) Add 1 ml of decalin.
4) Place large marble on top of each test tube.
5) Place tubes in aluminum block and bring to boil gradually; boil at approximately 124°C for one hour. Feed particles collecting above digestion fluid level should be returned to the boiling mass by washing down the sides with a small amount of warm NDF solution.
6) Filter through a previously weighed sintered glass crucible using a light suction.

Table 1. Comparison of neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin in esophageal fistula samples as obtained by 2 methods.

	NDF		ADF		Lignin	
Diet sample material	Micro	Macro	Micro	Macro	Micro	Macro
High grass, late spring						
Mean	56.72	58.91	39.41	39.26	7.10	6.73
Std. Dev.	2.10	1.68	.61	.92	.31	.42
Coef. Var.	3.70	2.85	1.55	2.34	4.37	6.24
High forb, late spring						
Mean	53.67	54.15	43.52[a]	42.90[b]	9.01	9.10
Std. Dev.	2.29	2.99	.71	.64	.58	.43
Coef. Var.	42.7	5.52	1.53	1.49	6.44	4.73
High grass, late summer						
Mean	67.81	66.10	52.76	53.18	10.93	11.25
Std. Dev.	2.14	3.16	.35	1.25	.51	.38
Coef. Var.	3.16	4.78	.66	2.35	4.67	3.38
High browse, late summer						
Mean	61.91	63.21	53.17	53.17	13.50[a]	14.18[b]
Std. Dev.	3.56	2.10	.87	1.00	.54	.46
Coef. Var.	5.75	3.32	1.64	1.86	4.00	3.24
High browse, fall						
Mean	68.26	67.19	56.89	56.78	10.60[a]	19.33[b]
Std. Dev.	2.12	1.11	.33	.67	.46	.68
Coef. Var.	3.11	1.65	.58	1.18	2.47	3.52

[a,b] Means with different letters are significantly different ($P<.05$).

7) Wash with hot water.
8) Repeat the washing with acetone until no more color is removed.
9) Dry at 100° C and weigh.

ADF Procedure

1) Weigh .35 g air dried sample, which has been ground through a #40 sieve, into a test tube.
2) Add 35 ml of ADF solution.
3) Add 1 ml of decalin.
4) Use procedures 4–8 of NDF procedure.

Lignin Procedure

1) Place crucibles containing dried and weighed ADF in a shallow enamel or glass plan containing 1 cm cold water. ADF in crucibles should not get wet.
2) Fill the crucibles half full with saturated potassium permanganate and buffer solution. Use a short glass rod to break lumps and draw permanganate solution up on sides of crucibles.
3) Allow crucibles to stand at room temperature for 90 minutes. Add more mixed permanganate solution if necessary. Purple color must be present at all times.
4) Remove crucibles to filtering apparatus and one by one, suck them dry.
5) Fill the crucibles again half full with demineralizing solution. With a glass rod move the contents taking care that all feed particles are under the solution and the sides of the crucibles are rid of all color.
6) After 5 minutes suck the crucibles dry and refill halfway with demineralizing solution. Rerinse the sides of the crucibles. Continue the treatment until the filter is white.
7) Fill and thoroughly wash crucibles and contents with 80% ethanol. Suck dry and repeat wash.
8) Wash twice with acetone as with ethanol.
9) Dry at 100° C and weigh.

Results and Discussion

The comparison of means for neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin in Table 1 shows significant differences existed between the two methods in 2, 1 and 2 of the 5 samples used for NDF, ADF and lignin analyses. The largest difference between means was obtained for NDF in a high grass sample. Coefficients of variation were highest for lignin followed by NDF and ADF analyses with both methods. The absolute differences between the two methods for ADF and lignin for a given diet sample were relatively small varying from .48 to 2.19 for NDF, .11 to .62 for ADF, and .10 to .73 for lignin. From a biological standpoint these differences appear relatively unimportant. In 4 of the 5 diet samples, variation in ADF values was higher for the macro-method than for the micro-method. However for NDF and lignin, less variation was associated with the macro-method in 3 of the 5 samples. When the macro-method was used, several NDF and ADF sub-samples presented filtering problems which at times resulted in erratic values and the necessity to rerun the sample. Waldern (1971) worked with samples that ranges from .31 to 7.38 percent acid detergent lignin. Data presented herein covered higher lignin levels that could typically be found in range forage and show the amount of variation associated with permanganate lignin.

In our study we did not run sequential analyses for NDF and ADF. Recent research by Mould and Robbins (1981) indicates that sequential analyses should be used for NDF and ADF if a highly precise determination of these fiber components is desired for browse. They also found that fiber partitioning for browse species was more accurate when sodium sulfite was left out of the NDF solution. We used sodium sulfite for NDF analyses in our study.

Compared to the macro-method the amount of time required to run 100 samples was reduced 75% with the micro-method because over four times as many samples were run at once, and filtration was faster and presented fewer problems. Another advantage of the micro-method was that a lower volume of solution was required per sample thereby reducing reagent use 65%. Our results may have been altered slightly if NDF and ADF analyses had been conducted sequentially and sodium sulfite had not been used in the NDF solution.

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Viewpoint

Soil Erosion Effects on Productivity in Rangeland Environments; Where is the Research?

GERALD F. GIFFORD AND JOHN M. WHITEHEAD

Abstract

The importance of erosion on rangelands has been recognized for many years. However, the impact of erosion on site productivity (choose your own index of productivity) has not been quantified to any extent for any rangeland plant—soil complex in the western United States. It is hoped that researchers over the next few years will shift their efforts to this neglected yet very important information void.

While some studies have been conducted on land under agricultural use relative to how its productivity is impacted by erosion, complimentary research type work has not been undertaken relative to rangeland. Soil productivity is the capacity of a soil, in its normal environment, to produce a particular plant or sequence of plants under a specified management system (Soil Sci. Soc. Amer. 1975). In most rangeland situations productivity is generally expressed in terms of yields, which reflect the ability to produce.

The National Soil Erosion-Soil Productivity Research Planning Committee (1981) has recently provided a research perspective for erosion-productivity research on agricultural lands. Their discussion of the erosion-productivity problem is in part applicable also to rangelands. Appropriate excerpts are given below.

The erosion-productivity problem:

> One of the most dangerous characteristics of the erosion-productivity problem is its difficulty of detection. . .Erosion reduces productivity so slowly that the reduction may not be recognized until land is no longer economically suitable for growing crops. . .
>
> The difficulty of detecting productivity losses is compounded by the nonlinear nature of the erosion process. Erosion generally increases future runoff because of reduced infiltration. Increased runoff reduces available soil water, thus plant growth. Of course, less plant growth means less residue. Less vegetation and residue provide less cover, which increases erosion. Because water erosion strongly relates to runoff. . . , increased runoff also leads to increased erosion. The process thus advances exponentially, and reversing it may quickly become economically impossible if it is not detected and controlled properly. . .
>
> Still another characteristic of the erosion-productivity problem is the difficulty of restoring the productivity of severely eroded soils. Restoration is generally difficult and costly because subsoil conditions often inhibit. . .growth. . .These conditions include poor aeration, low organic matter, lack of exchangeable or soluble nutrients and calcium carbonate, high soluble aluminum, gravel, and high density (strength). Although productivity can be partly restored by adding organic material and fertilizer, such additions may not be economical. For example, eroded rangeland is particularly difficult to restore because fertilization usually is not economical in low-rainfall areas. . .

Ways erosion reduces productivity:

> Erosion reduces productivity first and foremost through loss of plant-available soil water capacity. Lower soil water capacity subjects (plants) to more frequent and severe water stress. Plant-available soil water may be reduced by changing the water-holding characteristics of the root zone or by reducing the depth of the root zone. Erosion reduces root-zone depth if subsoils are toxic to roots or have high strength or poor aeration that retards root growth. The water-holding characteristics of the root zone are almost always changed when topsoil is removed because topsoil usually has a higher plant-available water capacity than subsoil.
>
> Erosion also reduces productivity by contributing to plant-nutrient losses. Eroded soil particles carry attached nutrients from fields into streams and lakes. Because subsoils generally contain fewer plant nutrients than topsoils, . . .fertilizer is needed to maintain. . .production.
>
> A third way erosion reduces productivity is by degrading soil structure. Degradation of soil structure increases soil erodibility, surface sealing, and crusting. . .Surface sealing and crusting reduce seedling emergence and infiltration. Reduced infiltration provides less opportunity for soil water storage.
>
> Erosion also reduces productivity through nonuniform removal of soil within a field. Erosion does not occur uniformly across a field mainly because of the runoff flow network and nonuniform topography. Selecting a management strategy to maximize production is nearly impossible in fields with various degrees of erosion. When fields are (treated) as units, fertilizer is normally applied uniformly over the field. If erosion is nonuniform, the application rate is more appropriate for some areas than others (optimal production is impossible for all areas).
>
> The effect on herbicide use is similar. Because herbicides interact with soils, their performance varies with soil organic matter content, pH, and cation exchange capacity. In a nonuniformly eroded field one rate of herbicide application may kill weeds and damage the crop in one part of the field but not effectively control weeds in another part of the field. . .
>
> . . .Nonuniform erosion also affects tillage effectiveness and causes inconsistent seedbeds that produce poor stands and variable emergence. . .

Authors are professor and chairman, Watershed Science Unit, and also director, Institute for Land Rehabilitation, Range Science Department; Mr. Whitehead, formerly of Utah State University, is currently employed by the State of Utah, Div. Oil, Gas, and Mining, Salt Lake City, Utah.

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Erosion studies, both under natural rainfall on small plots or watersheds or under simulated rainfall using mostly small plots, have been conducted in a number of rangeland situations. Examples include Osborn (1950), Meeuwig (1960, 1970), Wright et al. (1976), Hanson et al. (1978), Marston (1952), Blackburn and Skau (1974), Gifford and Skau (1967), Orr (1970), Williams et al. (1969), and Rich (1961), to name a few. Gifford (in press) has recently compiled a listing of most of the relevant erosion-related studies on rangelands. None of these, however, relate erosion to productivity.

Cooperrider and Hendricks (1937) found that cover density on rangeland in New Mexico was a function of erosion. As erosion increased from a "normal" rate to an "excessive" rate, cover density decreased from 35% to 13%. They also discussed some of the nutrient deficiencies associated with eroded soils, but these deficiences were not correlated with productivity.

Lyons and Gifford (1980a, b) looked at incremental soil depths on two pinyon-juniper sites in Utah in terms of infiltration rates, potential sediment losses, chemical water quality, plant production, transpiration ratios, and nitrogen-mineralization rates. Responses of these variables often changed significantly as a function of soil depth. In general, plant production and nitrogen mineralization rates decreased with "loss" of surface soils. Transpiration ratios increased significantly. Infiltration rates and sediment losses were not particularly affected, but phosphorus concentrations in runoff waters were increased somewhat. Results of similar studies are not available for comparative purposes.

Wight and Siddoway (1982) discussed the problems associated with developing soil loss tolerances for rangelands and indicated that the relationships between productivity and soil loss are only vaguely understood.

Conclusions

At the present time it is impossible to evaluate the impacts on productivity of differential rates of erosion on western rangelands. The National Soil Erosion-Soil Productivity Research Planning Committee advocates strongly the development of mathematical models and field experiments to support the models as a way to facilitate studying soil erosion-soil productivity relationships. Components of the model(s) should include hydrology, erosion-sedimentation, nutrient cycling, crop growth, tillage, and animal uptake for rangeland and pasture. However, given the state-of-the-art of erosion-productivity relationships on rangelands, *any* research on the topic would be useful. This is especially true for field studies (which may be designed around specific model-input requirements). Funding levels will have to be increased to accommodate this research because erosion-productivity studies are time-consuming and expensive. Concomitantly, scientific and public concern for productivity-related erosion impacts on western rangelands must be intensified. Without more vociferous concern, the necessary funding levels will never materialize.

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BOOK REVIEWS

Guide to Sources for Agricultural and Biological Research. Edited by J. Richard Blanchard and Lois Farrell. 1981. University of California Press, 2223 Fulton St., Berkeley, California 94720. 735 p. $47.50.

This new sourcebook was copyrighted in 1981, but first published on March 4, 1982. The work was sponsored by the U.S. National Agricultural Library, Beltsville, Maryland, and was edited by two library specialists of the University of California, Mr. Blanchard of the Davis campus and Ms. Farrell of the Berkeley campus. Each chapter has been developed by a team of contributors and reviewers, specializing in their respective areas.

Food production has received primary emphasis in this *Guide to Sources,* but support areas in biology within the pure sciences have also been included. It has been directed primarily to librarians, graduate students, and research scientists. Works published between 1958 and 1978 have been emphasised with some 1979 additions. *Literature of Agricultural Research* (University of California Press, 1958), of which this publication is essentially an enlarged and updated version, is suggested for older literature.

This work is not primarily an index to subject matter literature, but rather to sources that will lead to subject matter. "The purpose of this work is to describe and evaluate important sources of information for the fields of agriculture and biology with the major emphasis on agriculture and related subjects.... Types of sources described are primarily library 'reference' sources which lead to the primary literature, provide information about research in progress, organizations, and researchers in special fields, or serve as data compilations." For example, textbooks have been included only if they contain extensive bibliographies and in the absence of related specialized guides.

The first eight chapters are essentially divided on the basis of general agriculture and biology: general, plant sciences, crop protection, animal sciences, physical sciences, food science and nutrition, environmental sciences, and social sciences. The last chapter is appropriately entitled "Computerized Data Bases for Bibliographic Research." A total of 5,779 entries are included; most are annotated, but a few are indicated as "not examined." These bibliographic entries include a wide variety of publications and services: bibliographies, abstracts and indexes, reference manuals and dictionaries, encyclopedias and handbooks, library catalogs, reviews, directories, buyers' guides, information retrieval systems and services, congress and conference proceedings, literature guides, and audio-visual aid lists.

The chapters are divided into a maze of subsections combining types of literature-services and subject matter. Each chapter is provided with its own table of contents, and composite author, subject, and title indexes are included at the end of the guide. All entries are provided with a reference number which permits easy reference from the index. Range scientists will have to think broadly since "range" only has seven entries in the subject index and six entries in the title index.

Effective use of this guide will require careful study and persistent effort because of its complexity, but will prove rewarding. Useful explanatory and instructional material is scattered throughout most chapters in addition to the numbered entries. An "Introduction" section should not be overlooked since it gives helpful summation and treatment of methods of transmitting information, depositories of information, information networks, and literature search methods.—*John F. Vallentine,* Provo, Utah.

The Grasses of Baja California, Mexico. By Frank W. Gould and Reid Moran. 1981. San Diego Society of Natural History, Memoir 12. San Diego Natural History Museum, San Diego, California 92112. 140 p. $14.00

This book is a compilation of information pertaining to the grass flora of Baja California, Mexico, and a systematic treatment of the 274 grass species found within the region. This is the first book exclusively concerned with the grasses of the area which uses the six-subfamily classification scheme accepted by most contemporary agrostologists. Wiggins' *Flora of Baja California* (1980) also dealt with the Gramineae in its entirety, but followed the two-subfamily scheme presented in Hitchcock's *Manual of the Grasses of the United States* (1951).

The introduction to this book briefly describes the physiognomy, phytogeography and grass flora of Baja California, major grass collections, earlier works, and the scope of the present treatment. One obvious omission is the lack of climatic information for the area. While the habitats are diverse (as indicated by the phytogeography section), monthly precipitation and temperature data from specific localities throughout the penisula would be helpful to better understand the structure and phenology of the vegetation. Also included in the introduction, are three excellent figures which illustrate the special terminology for the grass plant, inflorescence, spikelet and floret.

The classification section is no more than a listing of the 19 tribes and 96 genera found in the area according to the grass subfamilies. The number of species described within each genus is given. The classification scheme is similar to that presented in Gould's *Grass Systematics* (1968) textbook except *Eleusine, Dactyloctenium* and *Leptochloa* are moved from the Chlorideae to the Eragrosteae, *Tragus* is transferred from the Chlorideae to the Zoysieae, and *Neeragrostis* is submerged with *Eragrostis.*

The genera key is in an indented and numbered format which is very convenient to use. It closely follows the keys presented in Gould's *Grass Systematics* (1968), *Grasses of Texas* (1975), and *A Key to the Genera of Mexican Grasses* (1979). The key is purely artificial (except to the Paniceae and Andropogoneae) but is as easy to use as any grass key. A notable omission is the lack of a glossary. While the figures in the introduction illustrate many of the major structures referred to in the key and systematic treatment, they do not replace a glossary. Users of the book, other than taxonomists, probably will have to use a supplemental glossary or a dictionary of botanical terms.

The systematic treatment is presented according to subfamily, tribe, genus and species. Also genera keys with more than one taxa are in an indented and numbered format. Along with the Latin name and author citation, the place and date of the original publication or description is given. The only synonyms included are those pertinent to the region. An English common name is presented for the most common species, and a Spanish common name is shown when applicable. Species descriptions are concise, well written, emphasize the most useful diagnostic characteristics, and the major structures (i.e., nodes, sheath, blade, inflorescence, spikelet, etc.) are italicized for easy reference. A general distribution is given for the most common taxa, while specific localities within Baja California are shown to indicate the range of less common species. Rare taxa are cited by collection. Frequent discussions of the systematic relationship of related species are presented, and at least one illustration is supplied for each genus. The contribution of the genus *Muhlenbergia* by C.G. Reeder should be noted. Her treatment of the large (22 species), diverse, and difficult genus is excellent.

The book is relatively free of typographical errors and the printing is of high quality; however, the large format (8 1/2 × 11) and paper binding is inappropriate for field use. Any difficulties with the keys or omission of taxa will not be apparent until the book has been used extensively. This book will serve as the standard reference for the identification of the grasses of Baja California for many years, and will be of invaluable assistance to ecologists, agrostologists, taxonomists, and land managers interested in the vegetation of the peninsula, southwestern U.S., and northwestern Mexico.—*Robert B. Shaw,* Gainesville, Florida.

Locking up the Range: Federal Land Controls and Grazing. By Gary D. Libecap. 1981. Ballinger Publishing Co., 54 Church St., Cambridge, Massachusetts 02138. 109 p. $14.50.

In the foreword J.R.T. Hughes states, "Professor Libecap uses the rangeland. . .as a fascinating laboratory for economic analysis. . . His analysis must stand as a challenge to those who support the present movement toward permanent government control and planning of the rangelands' future".

The book is organized into seven chapters: 1. "An overview: bureaucratic opposition to the assignment of property rights to the western range," 2. "Analytical framework: bureaucrats, ranchers, and property rights to the range," 3. "Open range—costs and informal property rights arrangements," 4. "The Interior Department and the land claims of ranchers," 5. "Grazing privileges and the Taylor Grazing Act, 1934-1960: secure rights to the range," 6. "Grazing rights and the Taylor Grazing Act, 1960-1980; bureaucratic control over the range," and 7. "A call for private property rights to the range." Each chapter is referenced and an index is provided. The author has a fluid writing style which is easily read and entertaining, and the rich historical perspective of BLM is worthwhile.

Professor Libecap focuses his book on rangelands currently managed by the Bureau of Land Management. Reference is made to general bureaucratic behavior with examples from the U.S. Forest Service, the Bureau of Indian Affairs, and the Bureau of Land Management (BLM). Libecape's view is that bureaucrats act with self-interested, discretionary behavior more sensitive to political than market forces. They will take action in response to political conditions even when the action reduces the total value of production. Libecap supports this view through numerous examples of BLM decisions and actions throughout its existence. He provides information comparing livetock productivity on public and private land through the late 1920's to substantiate that overgrazing occurred on untitled and unmanaged rangeland. This is reinforced with a theoretical economic mode to explain why overgrazing would occur under those circumstances. Professor Libecap progresses to the present BLM with an excellent coverage of budget changes, livestock stocking rates changes, and the development of laws and policies. His only attempt to explain ecological responses is a model of the growth rate of a grass stand under grazing. This explanation is more reflective of irrigated pasture responses than rangeland, but does illustrate his point that market conditions can influence stocking rate as much or more than forage availability. Also, multiple uses and related legislation are discussed.

Libecap's viewpoint is based on the perspective that market factors cycle in such a way that rangeland stocking will vary over the long term to yield stable forage supplies. Therefore, economics as a sole criterion will maintain producitivity of rangelands, management of rangelands based on principles of Range Science reduces wealth and is socially costly, bureaucrats are interested in building their careers irrespective of their impact on the resources or resource users, and livestock grazing is the only suitable use for rangelands except in limited areas with great amenity value. His conclusion is that title to BLM managed rangelands should be assigned to existing permittees since private property rights are the necessary conditions for restoring and maintaining the value of public rangelands.—*William C. Krueger,* Corvallis, Oregon.

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Information for Authors

The *Journal of Range Management* is an official publication of the Society for Range Management. The editor's objective is to publish in every issue something of value to each member of the Society and to others interested in range ecosystems and their management. Suitable articles from both nonmembers and members may be published upon approval of the Editorial Board.

Articles suitable for publication in the *Journal of Range Management* include high-quality papers concerning any phase of range ecosystems or their management. Short articles concerning research results, experimental equipment, or techniques may be published as a "Technical Note." Review papers on selected subjects also are acceptable but are usually invited.

All papers should be based on new and adequate information. The introduction should state clearly and concisely the purpose of the article and its relation to other work in the same field. Unsupported hypotheses and rambling discussion should be avoided. Organization of manuscript may vary to accommodate the content of the article, but the text should point any application of the results to range management problems.

For suggestions on writing and the preparation of manuscripts, authors are advised to consult *CBE Style Manual* (Fourth Edition, 1980) published for the Council of Biology Editors by the American Institute of Biological Sciences, 3900 Wisconsin Avenue NW, Washington, D.C. 20016.

All papers will be critically reviewed by associate editors or other subject matter specialists designated by them. Papers returned to authors for revision should be handled promptly. Unsuitable papers will be returned to the authors with an explanatory statement. Prior publication of a manuscript or concurrent submission to another outlet precludes publication in the *Journal of Range Management.*

All manuscripts should be addressed to **Dr. Patricia Smith, 2760 W. Fifth Avenue, Denver, CO 80204.**

Preparation of Manuscripts

1. For guidance on matters not specifically covered in the following paragraphs, see *CBE Style Manual,* cited above.
2. Manuscripts must be typewritten, double spaced with ample margins, on good quality white paper, preferably 8½ × 11 WITH NUMBERED LINES. Use only one side of the paper and NUMBER ALL PAGES. FOUR GOOD COPIES OF THE MANUSCRIPTS are to be submitted.
3. The title of the paper, several "key words" describing the paper for indexing, and the name, position, complete address, and telephone number of the author should be typed as distinct, well-spaced entries on a separate page.
4. An Abstract, typed on a separate page, should accompany each manuscript. The Abstract should succinctly state the purpose, major findings or conclusions, and their application.
5. Names of plants and animals must be shown in both common and scientific form the first time they are mentioned in the text; further mention should be by common name only. Authorities for scientific names may be included at the discretion of the author. Authors are encouraged to use the U.S. Soils Taxonomic List in designating soils.
6. The metric system should be used throughout the manuscript, but English units may be included in parentheses in the text.
7. Footnotes should be used very sparingly and numbered consecutively throughout the text. All text footnotes should be typed together (double spaced) on a separate sheet.
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10. The "Literature Cited" section (when used) should begin on a new page and citations should be listed alphabetically. References to citations in the text are to be by author and date, i.e., Jones (1949) or (Jones 1949). The "Literature Cited" section should be typed in the style of the following examples:

> **Pechanec, Joseph F., and George Stewart. 1949.** Grazing springfall sheep ranges of southern Idaho. U.S. Dep. Agr. Circ. 808. 34 p.
>
> **Sperry, Omer E. 1949.** The control of bitterweed *(Actinea odorata)* on Texas ranges. J. Range Manage. 2:122-127.

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