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Habitat-Effectiveness Index for Elk on Blue Mountain Winter Ranges

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Forward

Resource managers in the United States and Canada must face increasing demands for both timber and wildlife. Demands for these resources are not necessarily incompatible with each other. Management objectives can be brought together for both resources to provide a balanced supply of timber and wildlife. Until recently, managers have been hampered by lack of technique for integrating management of these two resources. The goal of the Habitat Futures Series is to contribute toward a body of technical methods for integrated forestry in British Columbia in Canada and Oregon and Washington in the United States. The series also applies to parts of Alberta in Canada and Alaska, California, Idaho, and Montana in the United States.

Some publications in the Habitat Futures Series provide tools and methods that have been developed sufficiently for trial-use in integrated management. Other publications describe techniques not yet well developed. All series publications, however, provide sufficient detail for discussion and refinement. Because, like most integrated management techniques, these models and methods have usually yet to be well tested, before application they should be evaluated, calibrated (based on local conditions), and validated. The degree of testing needed before application depends on local conditions and the innovation being used. You are encouraged to review, discuss, debate, and--above all--use the information presented in this publication and other publications in the Habitat Futures Series.

The Habitat Futures Series has its foundations in the Habitat Futures workshop that was conducted to further the practical use and development of new management techniques for integrating timber and wildlife management and to develop a United States and British Columbia management and research communication network. The workshop--jointly sponsored by the USDA Forest Service and the British Columbia Ministry of Forests and Lands, Canada--was held on October 20-24, 1986, at the Cowichan Lake Research Station on Vancouver lsland in British Columbia, Canada.

One key to successful forest management is providing the right information for decisionmaking. Management must know what questions need to asked, and researchers must pursue their work with the focus required to generate the best solutions for management. Research, development, and application of integrated forestry will be more effective and productive if forums, such as the Habitat Futures Workshop, are used to bring researchers and managers together for discussing the experiences, successes, and failures of new management tools to integrate timber and wildlife.

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Abstract

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An elk-habitat evaluation procedure for winter ranges in the Blue Mountains of eastern Oregon and Washington is described. The index is based on an interaction of size and spacing of cover and forage areas, roads open to traffic per unit of area, cover quality, and quantity and quality of forage.

Keywords: Winter range, wildlife habitat, elk, Oregon (Blue Mountains), Blue Mountains--Oregon, Washington (Blue Mountains), Blue Mountains--Washington.

Contents

Introduction

USDA Forest Service land managers in the Blue Mountains of Oregon and Washington have been using a habitat suitability index model for Rocky Mountain elk (*Cervus elaphus nelsonii*) summer ranges (or modifications of that model) developed by Black and others (1976) and Thomas and others (1979) to evaluate elk habitat conditions. Those original models stated (Thomas and others 1979, p. 114-115):

> ...cover requirements...on winter range must be considered more carefully than for summer range. Animals distributed over thousands of square kilometers at high elevation in spring, summer, and fall are forced by increasing snow depths to travel downslope...through spring-fall ranges and by midwinter are concentrated into smaller, more restricted areas....
>
> Most...winter ranges...are at lower elevations where forested areas are interwoven with openings...forest cover may be less than optimum, and existing cover is frequently the key to determining how animals will use the area....
>
> ...It is inappropriate to do the same for winter range because the consequences of error could be greatly magnified. Each winter range is different in its vegetative mosaic and the way it is used by the animals. The manager should study winter ranges carefully before deciding...to alter cover--particularly thermal cover.

We concur. New research on elk use of habitat on summer and winter ranges has become available, however (Leckenby 1984). Land-use planning requirements indicate that a model of elk winter-range habitat effectiveness is required.

Our purpose is to present a model (our working hypothesis) describing the most important habitat variables operating on elk winter ranges and their interactions. This proposed model should be field tested and calibrated as soon as possible.

Habitat Attributes

Variable 1. Size and Spacing of Cover and Forage Areas

Thomas and others (1979) thought that, based on elk use related to distances from cover-forage area edges, size and spacing of cover and forage areas were a key to elk use of forested habitats. Leckenby (1984) verified this hypothesis and described use patterns in the Blue Mountains.

Thomas and others (1979, p. 109) said, "Optimum...elk habitat is the amount and arrangement of cover and forage areas that result in the maximum possible proper use of the maximum possible area...." Leckenby (1984) showed that elk use of cover is disproportionately greater in cover areas within 200 yards (185.4 meters) of cover-forage area edges and of forage areas within 300 yards (278 meters) of such edges.

Thomas and others (1979, p. 104-127) defined two types of cover: thermal and hiding. Thermal cover was "any stand of coniferous trees 12 meters (40 ft) or more tall, with an average canopy closure exceeding 70 percent" (p. 114). Disproportionate use of such cover by elk was thought to be related to thermoregulation. Whether such thermoregulatory activity occurs or is significant has been argued (Geist 1982, Peek and others 1982). In the context of the model presented here, arguing about why elk show preference for such stands is pointless. They do exhibit a preference (Leckenby 1984; see Thomas 1979 for a review). As this habitat model is based on expressed preferences of elk, we continue to use that criterion as a tested habitat attribute. We cannot demonstrate that the observed preference is an expression of need, but we predict energy exchange advantages of such cover to elk (Parker and Robbins 1984). We consider it prudent to assume that preferred kinds of cover provide an advantage to the elk over nonpreferred or less preferred options.

Thomas and others (1979, p. 115) thought all levels of canopy closure provided some thermal advantage to elk and defined stands with canopy closures of 40-69 percent as "marginal thermal cover."

Hiding cover (Thomas and others 1979, p. 109) was defined as "vegetation capable of hiding 90 percent of a standing adult...elk from the view of a human at a distance equal to or less than 61 meters (200 ft)." Subsequent research (Leckenby 1984) revealed that, where satisfactory or marginal thermal cover was available, elk use of hiding cover per se was less than availability would indicate. No data were collected during hunting seasons; use of such cover could have been more extensive then.

Additional data suggest that a better model is attained by dividing cover into two classes--satisfactory and marginal. To avoid an argument over semantics, the term "thermal" has been dropped. Cover stands will be evaluated under whichever structural class they fit. Stands that fit neither satisfactory nor marginal cover definitions are called forage areas.

The definitions for the three classes of habitat then are: (1) Satisfactory cover is a stand of coniferous trees 40 or more feet (12 or more meters) tall, with an average canopy closure equal to or more than 70 percent; (2) marginal cover is a stand of coniferous trees 10 or more feet (3 or more meters) tall, with an average canopy closure equal to or more than 40 percent; and (3) forage areas are all areas that do not meet the definition of satisfactory or marginal cover.

Thus, all stands within the winter-range analysis area can be classified as satisfactory thermal cover, marginal thermal cover, or forage areas by using the chart in figure 1. The distribution of elk use related to distance from cover-forage edges (table 1) was analyzed (Oregon Department of Fish and Wildlife, unpublished data on file, Forestry and Range Sciences Laboratory, La Grande, Oregon). Weighting factors were derived from these analyses to be applied to the percentage of an analysis area within various distances from such edges (table 1).

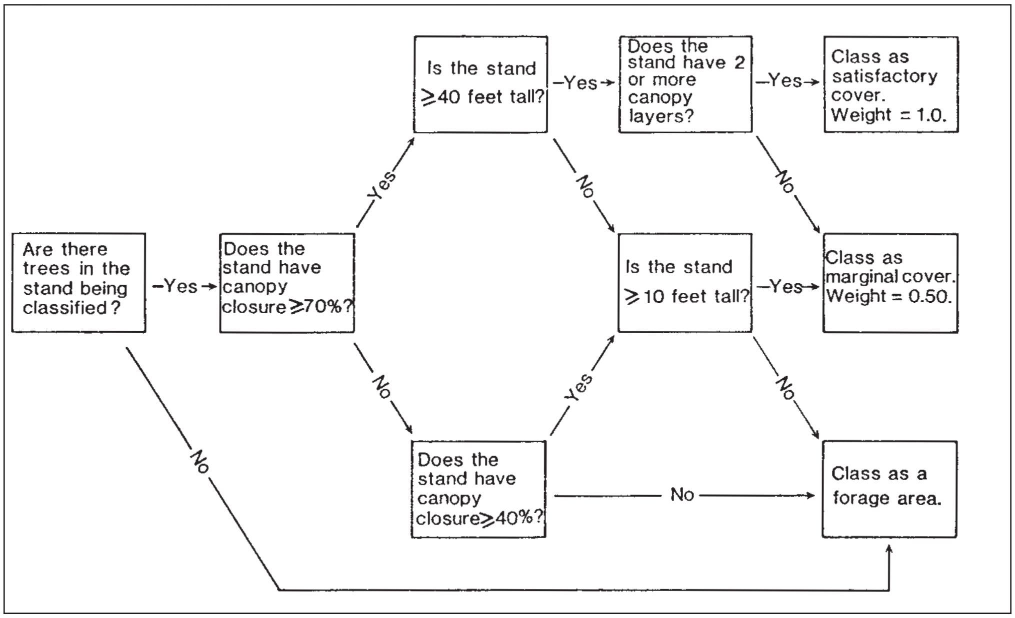

Figure I--A chart for classifying stands within the analysis area as satisfactory thermal cover, marginal thermal cover, or forage areas.

Table 1—Derivation of weights for use in determining habitat suitability for size and spacing of cover and forage areas[a]

Distance from edge into cover or forage	Elk plots	Total elk plots[b]	Weights: Largest number of elk plots[c]	Weights: Pooled weights by distance bands
Yards	*Number*	*Percent*	*Percent*	
COVER				
>1000[d]	2	0.2	0.01	
901-1000	0			
801-900	1	.1	.01	
701-800	0			
601-700	0			0.005
501-600	0			
401-500	3	.3	.01	
301-400	4	.4	.02	
201-300	21	2.0	.09	.14
101-200	43	4.0	.18	
1-100	250	22.0	1.00	1.00
Total plots into cover	324			
FORAGE				
1-100	302	26.0	1.00	1.00
101-200	203	18.0	.69	.54
201-300	115	10.0	.38	

Table 1—Derivation of weights for use in determining habitat suitability for size and spacing of cover and forage areas[a] (continued)

Distance from edge into cover or forage	Elk plots	Total elk plots[b]	Weights: Largest number of elk plots[c]	Weights: Pooled weights by distance bands
Yards	*Number*	*Percent*	*Percent*	
301-400	45	4.0	.15	.14
401-500	37	3.0	.12	
501-600	14	1.0	.04	
601-700	18	2.0	.08	
701-800	6	.5	.02	.04
801-900	14	1.0	.04	
901-1000	8	.7	.03	
>1000	57	5.0	.19	
Total plots into forage	819			

[a] Oregon Department of Fish and Wildlife, unpublished data on file, Forestry and Range Sciences Laboratory, La Grande, Oregon.
[b] Values derived by dividing the number of plots in a single band by the total plots.
[c] Weights derived by dividing the percentage of elk plots in each band by the highest percentage in any single band.
[d] The >1000-yard cover category is composed of three 100-yard bands; the >1000-yard forage area category, four 100-yard bands. Bands with similar weights were combined by adding the weights for the band and dividing by the number of bands.

In theory, all the analysis area lying within 100 yards (92 meters) of a cover-forage area edge would rate a perfect score of 1.0. Leckenby (1984), however, showed that, although the vast majority of elk used cover within the first 100 yards (92 meters) from cover-forage area edges, cover stands less than 133 yards (123 meters) in total width were used less frequently than stands at least that wide, and core areas of stands wider than 200 yards (184 meters) were used progressively less as the distance from edge increased. Therefore, we developed three rules not revealed by the weighting to apply to the relation between cover-stand widths and elk use: (1) Cover stands less than 200 yards (184 meters) wide are valuable and therefore receive the same weight (1.0) as do the first 100-yard (92-meter) bands into cover stands of greater width; (2) when cover-stand widths are being manipulated, widths maintained at less than 200 yards (184 meters) will reduce the actual use of those stands, regardless of the numerical score indicated, and (3) cover manipulation designed to maintain or enhance elk use should provide widths of 200 yards (184 meters) to 400 yards (368 meters) for the majority of cover stands. In other words, stands less than 200 yards (184 meters) wide are valuable and receive a score of one. But reduction in a stand width below 200 yards (184 meters) is apt to reduce elk use of such stands.

The procedure described here addresses the same relation of elk use to size and spacing of cover and forage areas described by Thomas and others (1979), using cover-forage area ratios. The ratio was "shorthand" for judging habitat effectiveness. Appropriate sizes of cover and forage areas were assumed to be met, and cover was assumed appropriately distributed between thermal and hiding cover. In practice, these assumptions frequently were not met. This made the cover-forage area criteria difficult to apply in habitat analysis except in a more general sense. According to Leckenby (1984), the size and spacing criteria described by Thomas and others (1979) remains valid. The technique described here to consider size and spacing of cover and forage areas eliminates the necessity for assumptions.

Variable 2. Density of Roads Traveled by Vehicles

Thomas and others (1979), using data published by Perry and Overly (1977) on elk use of habitat related to roads in the Blue Mountains, described a procedure to evaluate the impact of roads open to vehicular traffic on habitat effectiveness for elk. Lyon (1983) used a similar approach to evaluate the impact of roads on elk use of habitat. The two efforts yielded markedly similar relations. The relation between miles of roads open to vehicular traffic per square mile of habitat is shown in figure 2.

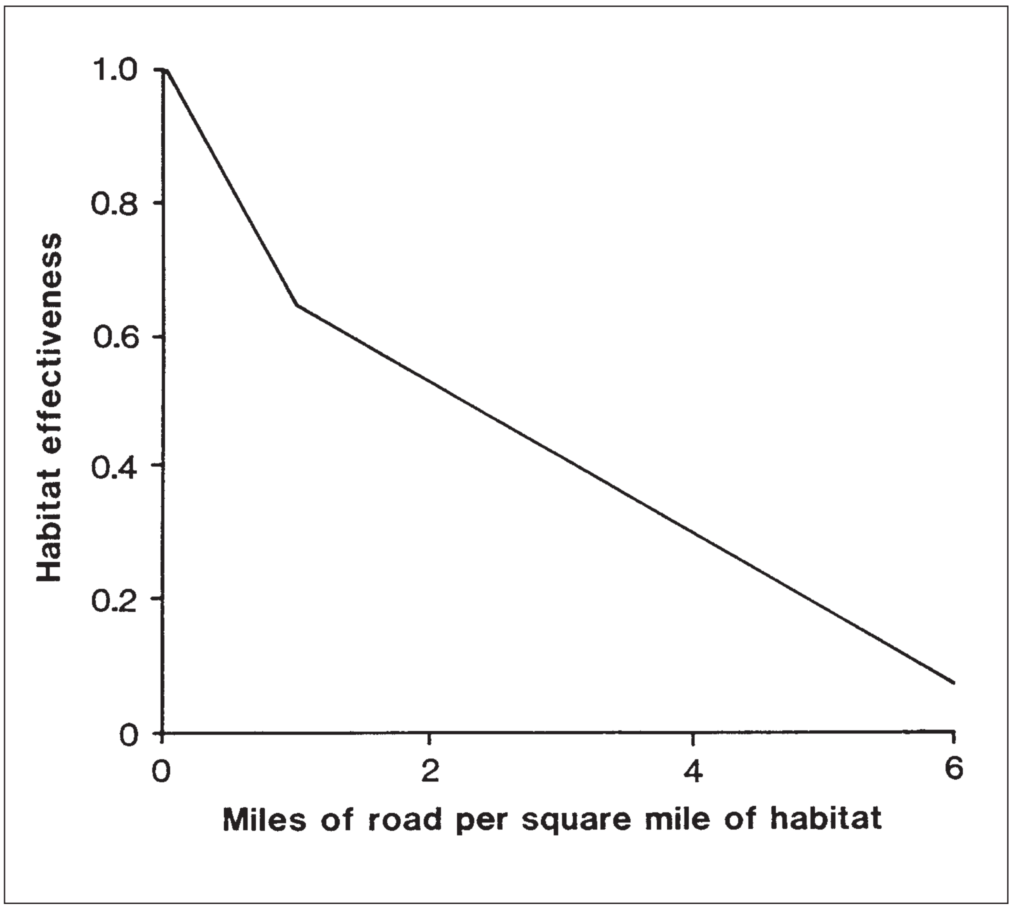

Figure 2--The relation of miles of roads open to vehicular traffic per square mile of habitat to habitat effectiveness.

No published information is available on the relation between vehicle trips per unit of time and the effect on elk use of adjacent habitat. Very rare use of roads seems unlikely to influence elk use significantly. Any traffic at all is a conservative definition of "open to vehicle use." If this definition is not acceptable, the criteria should be clearly stated and justified. Because knowledge is lacking about the relation between elk use of habitat and traffic volume, the conservative definition seems prudent.

Variable 3. Quantity and Quality of Forage

This relation is determined considering the quantity and quality of elk forages present in natural openings (that is, grasslands). The biomass of elk forage in the grasslands will usually be some larger but predictable multiple of the biomass in forested areas and on transitional rangelands intermixed with the grasslands. Grassland communities dominated by either Idaho fescue (*Festuca idahoensis*) or bluebunch wheatgrass (*Agropyron spicatum*) or both are used as examples. These common bunchgrass communities comprise much of the winter ranges in the Northwest (Hall 1973, Hopkins and Kovalchik 1983, Johnson and Simon 1985). Also, these species constitute common and preferred forage for Rocky Mountain elk (Nelson and Leege 1982).

The Thomas and others (1979) model to evaluate elk habitat effectiveness on summer and spring-fall elk ranges did not include forage availability per se. Either forage availability was assumed not to be a problem on such ranges or the evaluation of forage-cover area ratios was assumed to encompass availability. We think specifically including the quantity and quality of known key elk-forage species (Nelson and Leege 1982) is appropriate because: (1) Elk are concentrated on winter ranges, and their ability to shift to other areas is limited; (2) forage of adequate quantity and quality is often not available during winter; (3) livestock commonly graze winter ranges before elk migrate there in the fall, which influences the quantity and quality of the forage available; and (4) snow cover influences forage availability as well as the forage requirements of elk.

Factors in Considering Forage Quantity and Quality

In developing forage quantity and quality as a habitat attribute, we made these observations:

1. A sustainable yield of livestock and big game can be produced from managed forests and rangelands if positive balance exists between seasonally changing plant requirements and animal needs.

2. Interactions between grazing animals and their forage can be coordinated with plant physiology to schedule range management actions, such as grazing systems or prescribed burning.

3. Grazing by livestock and other range treatments can be scheduled to enhance forage quality and thereby increase nutritious food for wild ungulates (Austin and others 1983; Austin and Urness 1983; Gates and Hudson 1981a, 1981b; Gavin and others 1984; Hobbs and Swift 1985; Urness and others 1983; Willms and others 1980, 1981).

4. Dual use of range by livestock and big game is more flexible than the "either-or" use that most land management planning allocations suggest. The competition between classes of ungulates-elk and cattle, for example--is not complete. Competition is reduced by differential consumption of forage species and spatial and temporal distribution.

5. Forage quantity alone is not a sufficient index by which to judge habitat effectiveness; the interaction of forage quantity with quality is a more appropriate criterion.

6. The quality of fall forage consumed by elk regulates the amount of fat reserves elk can accumulate before winter.

7. Satisfactory cover on winter ranges helps prevent depletion of reserves of body fat before quality forage is available in the spring.

8. Spring forage is sufficiently nutritious and available to satisfy gestation requirements and build reserves of fat that will be used by elk during spring migration to summer range (Gates and Hudson 1981b, Holl and others 1979).

9. Habitat effectiveness is correlated with use of habitat by elk, physical condition of elk, and herd productivity.

10. Habitat effectiveness is poorly related to, and therefore not a good predictor of, densities of big game animals. Numbers of elk are influenced by factors not related to habitat effectiveness of a particular winter range. These factors include elk killed by hunters, weather conditions, conditions on other seasonal ranges, and snow depths.

The influence of forage availability on habitat effectiveness is judged by the interaction of the quantity and quality (Hobbs and Swift 1985) of the aboveground biomass remaining on key forage species as of October 1. The relationships are shown in figures 3, 4, and 5. In essence, the user of the model estimates the percentage of herbaceous plant cover that is comprised of decreasers (for example, ldaho fescue and bluebunch wheatgrass) and, from figure 3, determines the score for forage quantity. The user then estimates the percentage of plant height remaining on either ldaho fescue or bluebunch wheatgrass on October 1 and, from figure 4, determines the percentage of forage weight remaining. The score for the forage quality is next derived from the relation between weight remaining and habitat effectiveness (fig. 5). Finally, the scores for quantity and quality of forage are combined in a manner consistent with their compensatory interactions to derive the score for forage as described later.

Hobbs and Swift (1985) observed that only at intermediate or low dietary nutrient concentrations were estimates of carrying capacity from available biomass greater than those derived from the interaction of quantity and quality of forage. Analyses of ecosystems sustaining herbivores demonstrated that nutritional quality of herbage is inversely related to its abundance. An earlier model (Hobbs and others 1982) was used to estimate range carrying-capacity for cattle and beef production and forage improvements resulting from vegetation treatments in the Blue Mountains (Svejacr

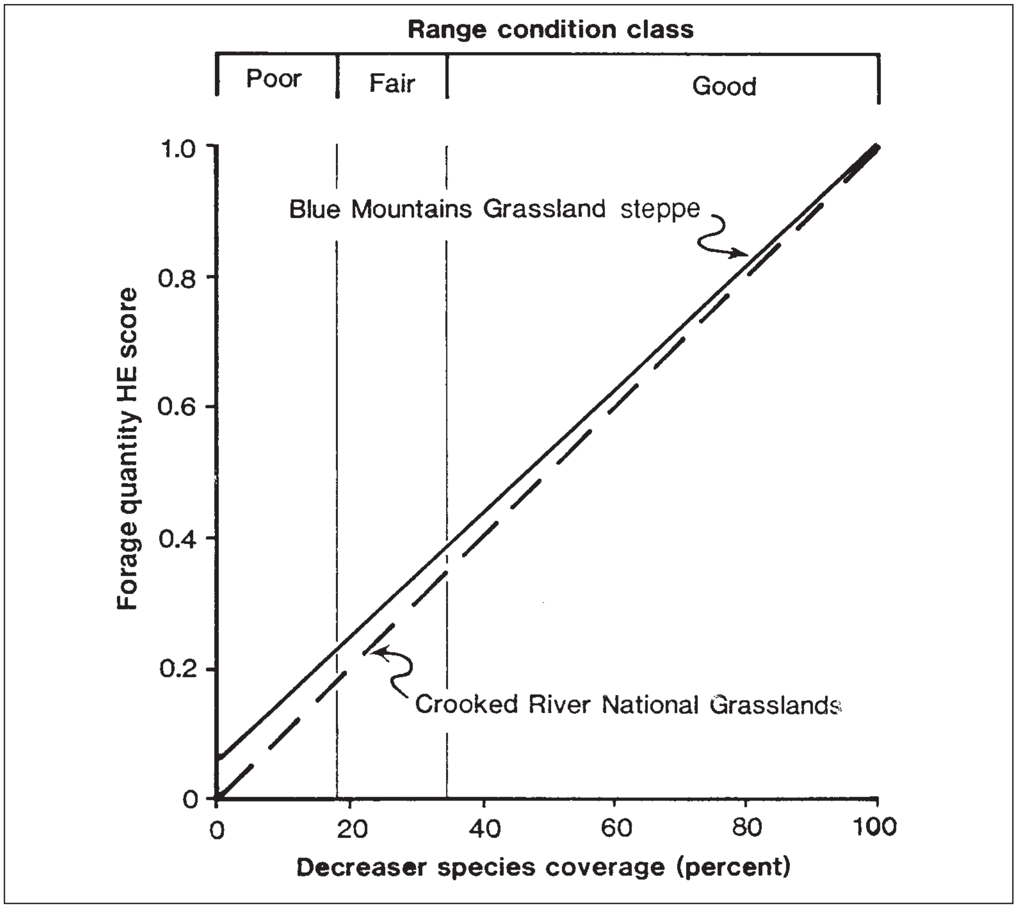

Figure 3--An estimate of total plant cover from decreaser species (for example, Idaho fescue and bluebunch wheatgrass) is used to determine the forage-quantity habitat effectiveness (HE) score (adapted from Hopkjns and Kovalchik 1983, Johnson and Simon 1985).

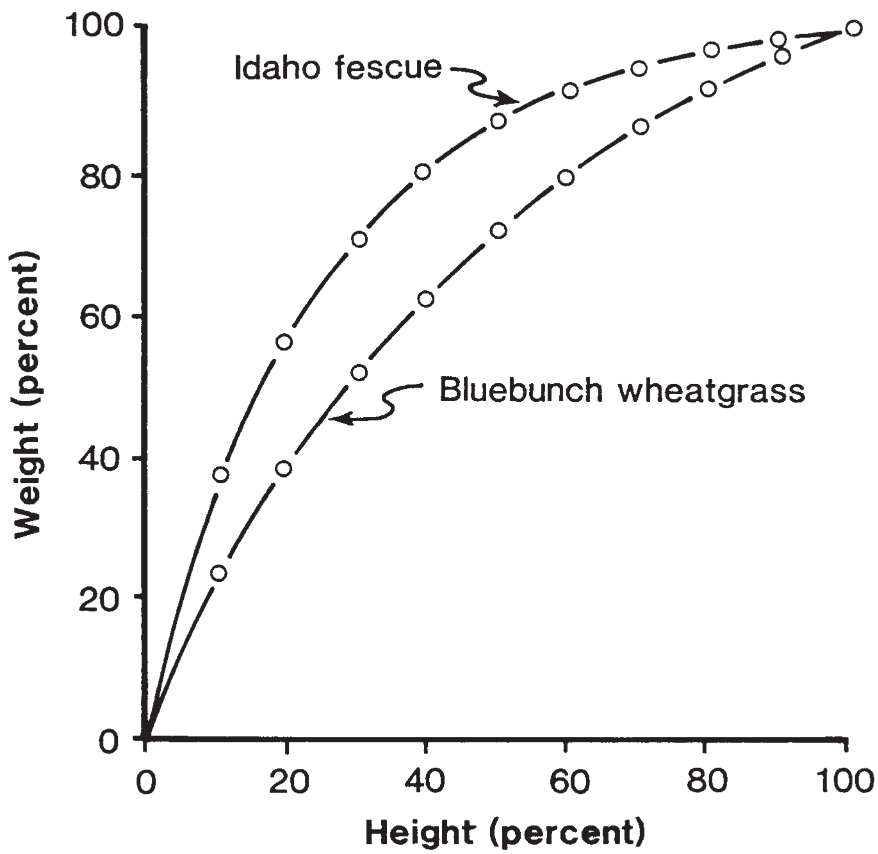

Figure 4--An estimate of grass height remaining on October 1 after grazing by livestock is used to estimate the weight of forage available to elk (data courtesy of F.C. Hall. 1985, personal communication).

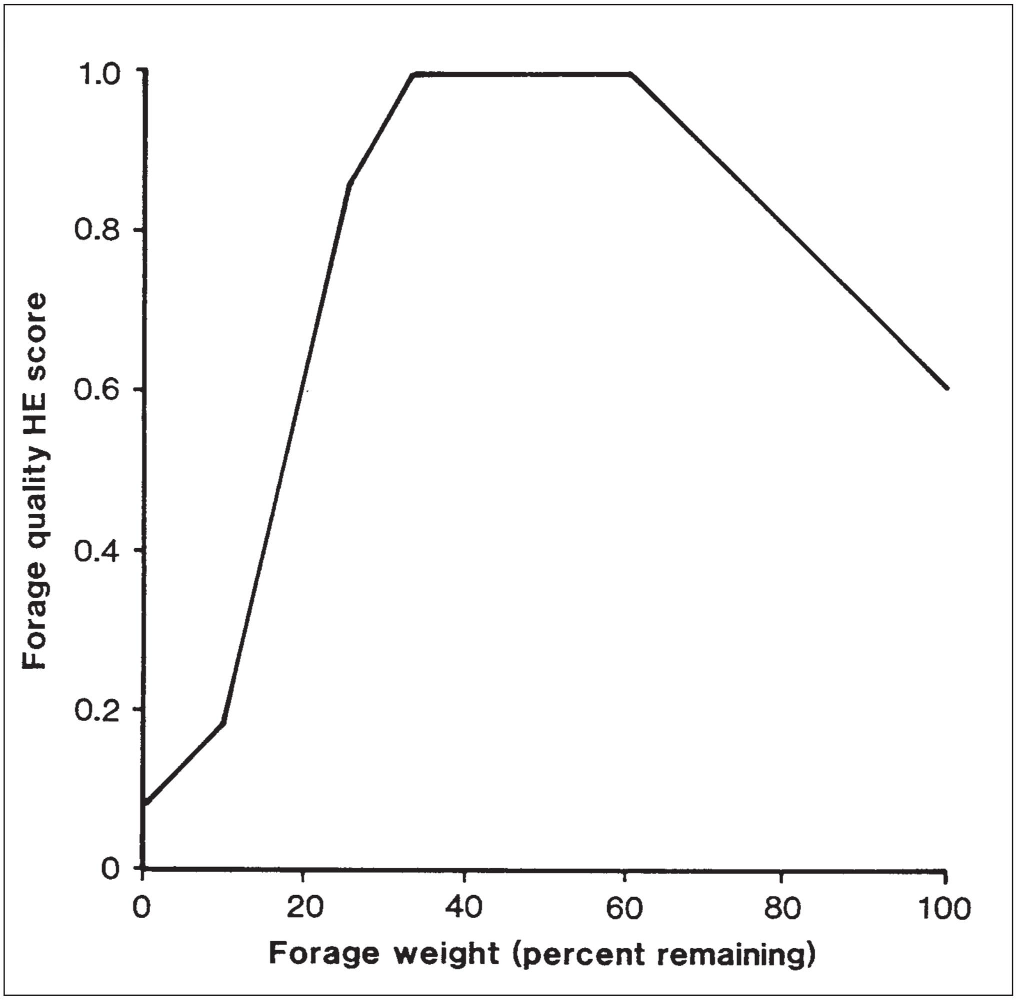

Figure 5--An estimate of the weight of forage remaining is used to determine the forage-quality habitat effectiveness (HE) score (data adapted from Hobbs and others 1982, Hobbs and Swift 1985).

We derived weights for the forage from the carrying-capacity relations proposed by Hobbs and Swift (1985). The Hobbs and others (1982) models resolve a paradox in evaluating carrying capacities among elk habitats. The models reliably predict the maximum quality of diets obtainable by a specified number of animals--for example, the number that is the current management objective for wintering elk on a particular winter range.

A diverse mosaic of forage conditions is desirable on winter ranges; some areas still retain most of the potential biomass on October 1, and some have had substantial portions of biomass removed. Such mosaics can be created by various range treatments, such as regulating livestock grazing and use of prescribed fire. Such diversity allows elk the opportunity to optimize the quality of their diet and to adjust quickly to changing weather conditions (Austin and Urness 1983, Gates and Hudson 1981a, Medcraft and Clark 1986). The diversity in the quantity and quality of forage remaining on October 1 between areas allows elk to minimize nutrient debits during periods of deep snow by using low-quality but high-quantity forage sticking out of the snow or found on windswept aspects. Forage intake rate is naturally (physiologically) depressed in winter (Gates and Hudson 1981b, Moen 1973, Robbins 1983, Robinette and others 1973). An analogy can be used to explain this process. Savings (deposited as body fat in summer and fall) are used to compensate for periods of deficit spending of energy over winter. The depleted savings are replenished with interest in spring when green, high quality forage is available to meet current energy expenditures and provide surplus that is stored as fat. At this time of year, forage intake is naturally increasing.

Variable 4. Evaluation of Cover Quality

Habitat effectiveness as influenced by the amount and distribution of cover is accounted for by variable 1 (size and spacing of cover and forage areas). In variable 4, we consider the influence of the quality of cover. Satisfactory cover and marginal cover were defined earlier (fig. 1).

Based on observed differences in elk preference (Oregon Department of Fish and Wildlife, unpublished data on file at Forestry and Range Sciences Laboratory, La Grande, Oregon) for these classes of cover, weights were assigned: satisfactory thermal cover, 1.000; marginal thermal cover, 0.500.

Selection of an Analysis Area

Each analysis area must be permanently delineated so that both individual and cumulative impacts of management activities can be evaluated on the same area. The analysis area should be large enough to be meaningful for elk use of a particular winter range and, to the extent possible, compatible with other recordkeeping needs of the manager. The selection criteria are otherwise flexible and left to the manager's discretion. Once defined, however, the evaluation area becomes the permanent base on which elk-habitat effectiveness is determined and management alternatives are evaluated. Boundaries must not be altered as part of an analysis; such alteration can cause significant changes in the habitat-effectiveness index. Timber sales, silvicultural treatment, and impacts of roads are best evaluated on individual treatment areas-such as a timber sale area. Overall effects of such actions on elk-habitat effectiveness (that is, impact on the entire analysis area) must then be evaluated for the cumulative effects of management actions on elk-habitat management objectives. lnstallation and evaluation of a series of smaller scale actions that meet management criteria without accounting for cumulative effects can, and usually will, inadvertently produce elk-habitat effectiveness levels below those selected as a management goal.

The Habitat-Effectiveness Index

The habitat-effectiveness (HE) index for an elk winter range is computed by the following procedure:

$$HE_{SRFC} = (HE_S \times HE_R \times HE_F \times HE_C)^{1/N} ;$$

where

HE_{SRFC}	=	habitat-effectiveness index, allowing for the interaction of HE_S, HE_R, HE_F, and HE_C,
HE_S	=	habitat-effectiveness index derived from size and spacing of cover and forage areas,
HE_R	=	habitat-effectiveness index derived from the density of roads open to vehicular traffic,
HE_F	=	habitat-effectiveness index derived from the quantity and quality of forage available to elk,
HE_C	=	habitat-effectiveness index derived from cover quality,
1/N	=	Nth root of the product taken to obtain the geometric mean, which reflects the compensatory interaction of the N factors in the HE model.

The geometric mean, or compensatory function (which assumes interactions among and between the variables), is used in such multiplicative models so that partial compensation for the interacting variables is accounted for (U.S. Fish and Wildlife Service 1981). Optimum conditions exist only if all HE values are 1.0. If any HE value is zero, the output of the function is zero. A low value (other than zero) for one variable will be partially compensated for by higher values of the other interacting variables.

The index resulting from raising any product derived from ($HE_S \times HE_R \times HE_F \times HE_C$) to the power of 1/N (1/4 in this case) can be determined from figure 6. The procedural steps for determining HE values are demonstrated by applying them to a hypothetical analysis area with cover and forage distributed as shown in figure 7.

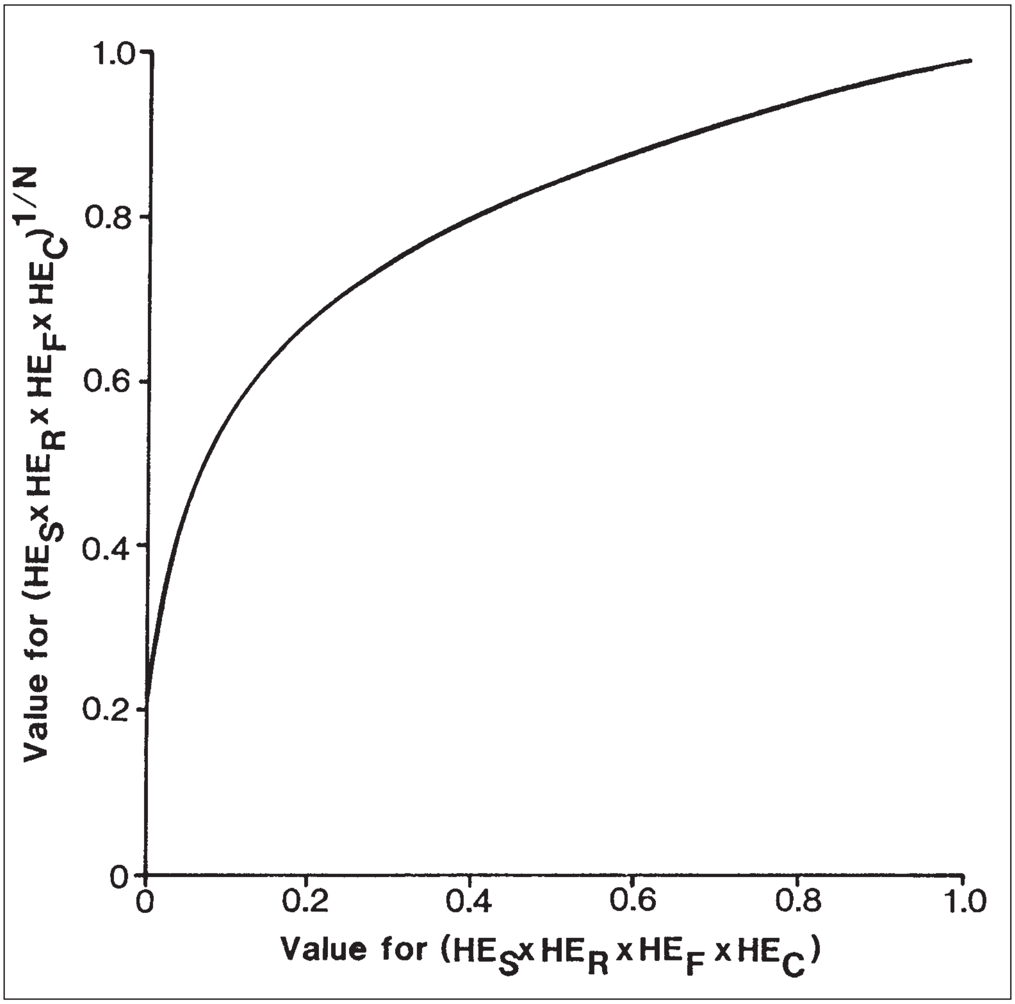

Figure 6--Conversion for (HE_S x HE_R x HE_F x HE_C) to (HE_S x HE_R x HE_F x HE_C)$^{1/N}$.

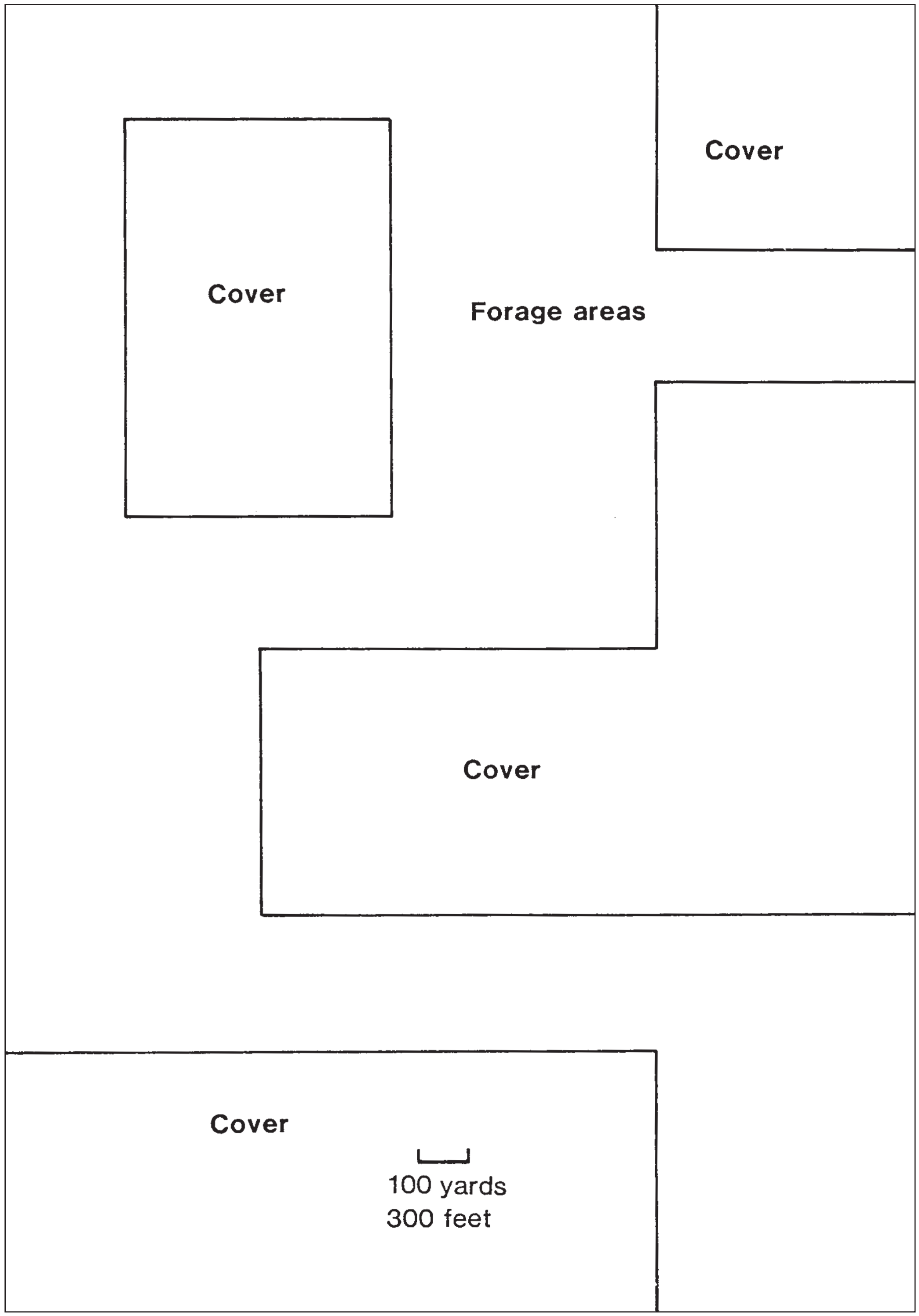

Figure 7--Distribution of cover and forage areas on a hypothetical analysis area.

Deriving an Estimate of Habitat Effectiveness on an Example Area

Step 1. Computation of HE_S. Habitat effectiveness for size and spacing (HE_S) is derived by examining a map of the analysis area showing the distribution of cover (satisfactory and marginal thermal cover) and forage areas. Computations are then made of the amount of area lying within various bands of distance from cover-forage edges (see table 1). Such an analysis can be made either from standard maps by manual procedures or from digital data available from LANDSAT satellites. The techniques and procedures for obtaining the necessary information from LANDSAT are automated and available to managers (Isaacson and others 1982; Leckenby 1979, 1984; Leckenby and others 1985; Murray and Leckenby 1985).

The distribution of land area by 100-yard (92-meter) bands from cover-forage area edges is shown in figure 8. HE_S is computed by multiplying the weights for each distance band from the nearest cover-forage edge (table 1) times the percentage of the analysis area within each band (fig. 8). These products are then summed to give the value for HE_S. This procedure is illustrated in table 2. The resulting HE_S for this example is 0.61.

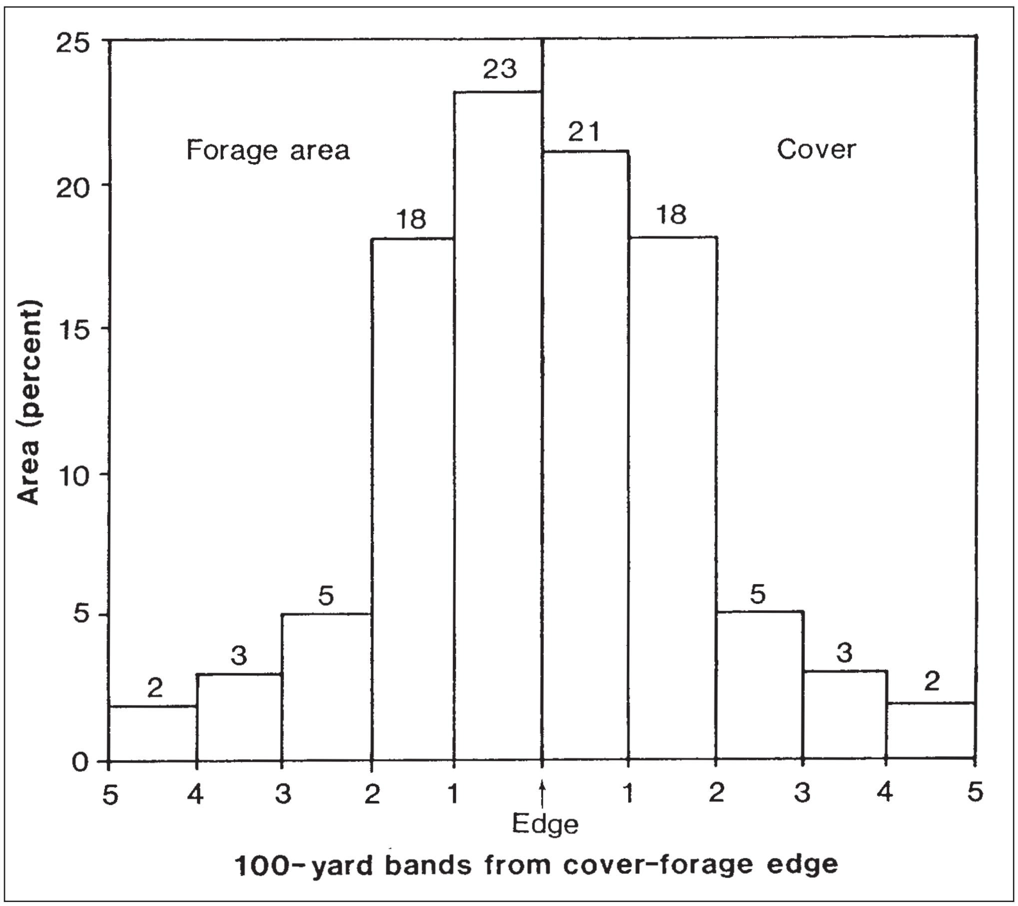

Figure 8--Percentage of the analysis area in 100-yard bands from cover-forage area edges.

Table 2—Computation of example HE_S

Habitat component	Distance from cover-forage area edge	Weight	Analysis area in the band	Contribution to cumulative HE_S index
	Yards		*Percent*	
Cover	400	0.005	0.02	0
	101-400	.140	.26	.04
	1-100	1.000	.21	.21
Forage	1-100	1.000	.23	.23
	101-300	.540	.23	.12
	301-500	.140	.05	.01
	500	.040	0	0
HE_S				.61

When the impact of various vegetative treatments is evaluated, the resulting redistribution of cover and forage areas is mapped, and the new proportion of areas that fall in the distance bands from the cover-forage area edges is recalculated. The resulting HE_S (after treatment) is then compared with the pretreatment HE_S or that from other alternative treatments.

Step 2. Computation of HE_R. Habitat effectiveness as influenced by roads open to vehicular traffic is considered next. The miles of roads open to vehicular traffic are determined for the analysis area. These data are converted to a density figure as follows :

Road density = miles of roads open to vehicular traffic/square miles in the analysis area.

This example has 50 miles of roads. Thirty miles of those roads are open to vehicular traffic, and the analysis area encompasses 10 square miles. The density of roads open to vehicular traffic is, then:

Road density = 30/10 = 3 miles/square mile.

Now, refer to figure 2. The HE_R at a road density of 3 miles/square mile is 0.42.

Step 3. Computation of HE_F. Habitat effectiveness resulting from forage quantity and quality (HE_F) requires on-the-ground inspection.

The procedure to be used is as follows:

1. The percentage of herbaceous cover made up of decreaser species (that is, bunchgrasses) and the percentage of height of Idaho fescue and bluebunch wheatgrasses remaining on October 1 are determined (figs. 3 and 4).

2. Bluebunch wheatgrass makes up 50 percent of the herbaceous cover, which corresponds to an HE_F score of 0.5 (from fig. 3).

3. If 20 percent of the height of bluebunch wheatgrass remains, 34 percent of the aboveground biomass is determined to remain (from fig. 4).

4. This weight of biomass of bluebunch wheatgrass remaining (that is, 34 percent) is used to determine the forage-quality portion of the HE_F score from figure 5 which, in this example, is 1.0.

5. The interaction of the two scores (forage quantity and forage quality) of 0.5 and 1.0 is computed by the following formula:

$$\begin{aligned} HE_F &= (HE_{Quan} \times HE_{Qual})^{1/N} \\ &= (0.5 \times 1.0)^{1/2} \\ &= 0.71. \end{aligned}$$

Step 4. Computation of HE_C. Cover is in one of two classes described earlier, satisfactory or marginal.

The percentage of cover in each of the two classes is computed next. Multiply the percentage in each class by the weight applicable to that class (satisfactory, 1.00; marginal, 0.50). In this case, 60 percent of the cover is satisfactory cover, and 40 percent is marginal. The HE_C index is derived as shown in table 3.

Table 3—Computation of example HE_C

Cover class	All cover	Weight	Contribution to cumulative HE_C[a]
	Percent		
Satisfactory	60	1.0	0.6
Marginal	40	.5	.2
HE_C			.8

[a] Derived by multiplying percentage of the cover in the class by weight for the class and dividing that product by 100.

Step 5. Computation of HE_{SRFC}. Overall habitat effectiveness (HE_{SRFC}) considers the interaction of: (1) size and spacing of cover and forage areas (HE_S), (2) density of roads open to vehicular traffic (HE_R), (3) forage quantity and quality (HE_F), and (4) the quality of cover (HE_C). It is computed as follows:

$$\begin{aligned} HE_{SRFC} = \; & (HE_S \times HE_R \times HE_F \times HE_C)^{1/N} \\ & (0.61 \times 0.42 \times 0.71 \times 0.80)^{1/4} \\ & (0.15)^{1/4} \\ & 0.62 \text{ (as derived from fig. 6).} \end{aligned}$$

Associated Land Management Techniques

The HE index describes habitat effectiveness for elk on Blue Mountain winter ranges by evaluating four variables within a delineated management area (1) size and spacing of cover and forage stands, (2) cover quality, (3) roads open to vehicular traffic, and (4) quantity and quality of forages. Other activities on winter ranges influence these attributes of elk habitat. Klemmedson (1967) listed the following activities and agents as the most important contributors to the downward trend of winter ranges: forestry and range management; wildfire; ecological succession; overuse by livestock and big game; insects; disease and rodents; roads and highways; recreation; urban expansion; flood and soil erosion; and water development projects.

We now describe relations of several management techniques to modify the activities and agents mentioned. Each is examined by how they might be applied to winter ranges to minimize adverse impacts, to mitigate effects of past management activities, or to improve habitat conditions for elk.

Timber-Management Activities on Winter Range

Timber-management activities conducted on winter range in winter months can be particularly disturbing to elk. In a study of habitat use in a logged and unlogged forest environment on summer range, elk use of newly logged areas during the summer of logging and the next year was depressed (Pedersen and others 1980). Beall (1976) suggested that logging activity on a winter range caused initial avoidance by elk that lasted 2 weeks. After that period, elk resumed normal activities. Areas receiving light to medium use by elk in the winter before logging received no use by elk the winter after logging.

Parker and others (1984, p. 486) suggested that "Logging affects energy requirements of elk by influencing snow depth through removal of canopy interception of falling snow." Essentially, the elk uses more energy moving through deeper snow, and less forage is readily available. During a storm, more snow accumulates in created openings than in adjacent forested stands because snow interception is greater in the forested stands. Much of the snow that falls in the open and piles up on the surface would never reach the ground in the forest.

Management Tips for Logging

- Restrict logging of winter ranges to times when elk are absent (spring, summer, and fall).
- If logging is conducted in the winter, concentrate activities into the shortest time and smallest area possible.
- Provide "security areas," where no management activities are underway adjacent to active timber sales. Provide an area at least as large as the sale area, with line-of-sight topographic barriers, and closed to vehicular traffic (Lyon 1979, 1980; Ward and others 1980).
- Do not log adjacent drainages simultaneously (Thomas and others 1979).
- Plan logging to provide a diversity of cover classes throughout the winter range area.

Improving Forage Quantity and Quality With Prescribed Burning

Historically, fire was the most important factor affecting plant succession and species on most lower elevation sites that are now winter ranges (Dell 1980, Gruell 1980, Houston 1982). Gruell (1980) suggested that a reduction in acres burned has allowed vegetation to reach advanced succession at the expense of herbaceous plants and deciduous shrubs and trees. With advancing succession, the carrying capacity for elk declined.

Results from prescribed fires, designed to improve forage on winter range, are as diverse as the habitats on which they were conducted. Skovlin and others (1983) concluded that fall burning on a foothill rangeland in the northern Blue Mountains did not increase elk use during winter. Burning was conducted after fall rains had begun; this may have influenced production of forage on the treatment plots.

In mixed conifer/pinegrass communities studied by Hall (1977), prevention of under-burning decreased elk forage (pinegrass [*Calamagrostis rubescens*] and elk sedge [*Carex geyeri*]--the most palatable plants) and increased tree cover. Forage production was only 50 to 100 pounds per acre (56 to 112 kg/ha). In the same community type where periodic underburning had occurred, tree canopy averaged 50 percent and forage production was 500 to 600 pounds per acre (560 to 672 kg/ha). A portion of the increase in forage production on burned plots may have been attributable to the decreased canopy closure of the trees (McConnell and Smith 1970k thus, probably not all the additional forage resulted from the effects of fire per se.

Hobbs and Spowart (1984) warned that inferences on the benefits to ungulates from prescribed fires may severely underestimate the values of burning to the nutrition of big game if those inferences are based only on changes in forages and not on changes in diet. They observed that prescribed burning greatly improved the quality of winter diets of mountain sheep (*Ovis canadensis*) and mule deer (*Odocoileus hemionus*) in two plant communities but only small changes in quality of individual forages were noted. More green grass was observed on burned plots than on unburned plots in the winter, primarily because of removal of standing dead herbage and warmer soil temperatures, the latter being enhanced by greater absorption of sunlight by blackened soil surfaces.

Ungulates were able to select more weight of highly nutritious green grasses from burned plots and, consequently, to alter significantly the quality of their diet. Spring forages on control plots were phenologically younger and therefore higher in quality than on burn plots because growth had started earlier in the spring on the burned plots. Differences in initiation of plant growth between burned and control plots benefit ungulates by offering two temporally, distinct flushes of nutritious plant tissue, early on the burn and late on the control. This prolongs the time when nutritious forage is available to ungulates.

Such results emphasize the importance of diversity of habitats and treatment conditions in providing forage choices for ungulates under various climatological and snow conditions.

Factors that can influence whether a prescribed burn will meet desired objectives for forage enhancement follow:

1. The heat tolerance of the forage species. The morphology of a plant has a direct influence on its tolerance to heat. For example, bunchgrasses in general have low tolerance to fire because their densely clustered culms can burn for several hours. Among the bunchgrasses, wheatgrasses are the most heat tolerant because their coarse stems burn out quickly.

2. Fire resistance of the forage species. Resistance of a plant to burning is related to carbohydrate reserves. Such reserves are generally lowest during the active growing season, and burning during this time can be damaging to some species.

3. Time of year. Spring burning of Idaho fescue can cause damage or mortality to the plant, whereas burning in the fall after the plants have become dormant will cause little damage.

Prescribed burning as a technique to improve forage quality for ungulates has had mixed results. the response of elk to prescribed burning on winter range must be closely evaluated to assure that specific objectives are achieved.

Fertilization With Chemicals

Information on use of fertilizer to improve forage quantity and quality for elk on winter range is scarce. Skovlin and others (1983) observed that fertilizing winter range in the northern Blue Mountains in fall increased elk use in the winter by 49 percent the first winter after application. No carry-over effects were observed in elk response in succeeding years. Applying fertilizer was not cost-effective but may be beneficial in certain situations.

Bayoumi and Smith (1976) reported an increase in forage quantity and quality after fertilization of a sagebrush-grass-type winter range and suggested that fertilization may not prove cost-effective in increasing elk use where sufficient forage is available to meet normal winter requirements.

As with prescribed burning, fertilizing rangelands to improve quantity and quality of forage has had mixed results. Skovlin and others (1983) recommend that land managers contemplating fertilization develop simple field trials on individual winter ranges to determine feasibility under various range conditions.

Grazing by Domestic Livestock

Using livestock to improve forage conditions on big game winter range is the subject of considerable debate. In separate grazing studies conducted on elk winter ranges in northeastern Oregon, opposite conclusions about the effects of livestock grazing on elk use were presented. Anderson and Scherzinger (1975) thought that light grazing by cattle in spring and early summer stimulated regrowth that was higher in nutrients than ungrazed range. This improved forage was thought to have attracted additional elk to the study area. Conversely, Skovlin and others (1983) observed that elk use declined on areas that were grazed in the spring by cattle on winter range (measured by counts of pellet groups) during the second winter of a 3-year study in northeastern Oregon.

The disparity between the two studies might be explained by Collins and Urness (1979), Hobbs and Spowart (1984), and Hobbs and Swift (1985). Collins and Urness (1979) reported that "distribution of elk pellet groups did not give accurate representation of relative habitat segment use." Elk defecated at a greater rate when active, such as walking from one area to another. Other work by Collins (1977) indicated that elk move about less in more productive habitat-the most preferred for grazing. Pellet-group counts underestimate elk use in these rich-forage areas because elk travel less when feeding there, and they defecate less often when they are less active.

Hobbs and Spowart (1984) observed that improvement in diet quality for ungulates after fire was related to green grass on burned plots. Green grass on unburned sites was obscured by standing dead herbage and litter on the ground. Austin and others (1983) observed this with mule deer also. Hobbs and Swift (1985) noted that burns contained more forage with high nutrient concentrations but less forage overall. They noted that forage quality is inversely related to its abundance in many ecosystems.

These observations can be related to the data collected by Skovlin and others (1983). The grazed plots were structurally similar to the burn plots of Hobbs and Spowart (1984k that is, dead herbage was removed and green forage was more available. The elk-use data of Skovlin and others (1983) may have been misinterpreted in light of the work by Collins and Urness (1979); we would expect fewer pellet groups on grazed plots because more highly nutritious green forage would be available to elk. This is further supported by the observation of Skovlin and others (1983, p. 187) related to the reduction in elk use (pellet counts) during the second winter, "The winter with the least snow and heaviest elk use." The details of this observation are not known. If elk concentrations were high and green forage was more available on grazed plots, we would expect fewer pellet groups on these plots.

Anderson and Scherzinger (1975) developed a livestock grazing system based on the morphological and physiological characteristics of forage plants. The objectives were to remove dead herbage to prevent formation of wolf plants and to improve quality of forage regrowth by manipulating the physiology of forage plants through livestock grazing. This concept has been strengthened through the work of Hobbs and Spowart (1984), Hobbs and Swift (1985), and Pitt (1986) and it supports distributions of elk and deer observed on many winter ranges.

In studies of northeastern Oregon rangelands (Miller and Vavra 1981) and elk range in Yellowstone (Houston 1982), south exposures and windswept ridges provided a major portion of winter forage consumed by deer and elk. These areas continued to be important into early spring because they provided a new source of abundant green forage. These areas had the greatest potential for competition for forage between livestock, elk, and deer.

Forage in Cover Stands

Forage inside cover stands is important to elk in periods of deep snow when forage is not available in open areas. Canopy intercept of snow reduces snow depth inside these stands and makes forage more available (Leckenby 1984, Parker and others 1984). Leckenby (1984) observed abundant lichens (*Alectoria* sp.) that were much used by elk inside satisfactory cover stands. Samples of this rich and often overlooked elk food contained 1.99-2.24 M cal of digestible energy per kilogram of dry matter and 6-7 percent crude protein.

A diversity of crown closures in cover stands and forage areas on winter range will provide elk with foraging opportunities that can be used in response to varying climatological and snow conditions. This, in turn, seems likely to enhance survival and optimize productivity (Beall 1976, Leckenby 1984, Moen 1973, Parker and others 1984, Wickstrom and others 1984).

Management Tips on Providing Forage

- A diversity of forage conditions (in terms of forage structure; that is, grazed, burned, forage inside cover, ungrazed) will provide an array of grazing opportunities under varying climatological and snow conditions.
- Use of a livestock-grazing system keyed to the physiology and morphology of the forage species to improve forage quality on winter range can improve the nutritional status of wintering elk.
- Prescribed burning, judiciously applied, holds promise for improvement of forage quality on winter range if management objectives provide an array of forage conditions.
- Use of fertilizers to improve forage quality on winter range is not usually cost-effective.

Road Management on Winter Range

Roads affect elk by removing elk habitat from production of plants and by introducing a disturbance factor (vehicles), which reduces the use of elk habitat adjacent to roads (Compton 1975, Lyon 1979, Marcum 1976, Morgantini and Hudson 1979, Pedersen and others 1979, Perry and Overly 1977, Rost and Bailey 1974).

Cupal and Ward (1976) concluded that sufficient evidence indicates that direct and indirect effects of road construction, logging, vehicles, and harassment affect elk physiology negatively. These effects were briefly discussed by Ward and others (1976).

Aune (1981) and Richens and Lavigne (1978) observed that the greatest flight distances for elk on winter range were in response to human disturbances, such as those caused by skiers or hikers. Unanticipated disturbance seemed to be the most detrimental to wintering animals.

Energy expenditure calculations by Severinghaus and Tullar (1975) demonstrated the danger of snowmobile harassment to deer in winter. Flight distances caused by snowmobiles averaged about 37 yards for elk compared with 59 for skier interactions in Yellowstone National Park (Aune 1981, Parker and others 1984).

Parker and others (1984) suggested that the add tional energy drain an wintering wild ungulate populations after disturbance by winter recreationists on poor winter ranges may be an important factor in survival of the population.

Management Tips for Roads on Winter Range

- Restrict human access to winter ranges if the welfare of elk is a primary concern (Parker and others 1984).
- Elk welfare should be a primary consideration in the design and management of roads on elk winter ranges (Pedersen and others 1979).

Summary

Habitat effectiveness is an index accounting for elk-habitat conditions on winter ranges in managed forests. The index relates to potential levels of elk use of habitats, elk productivity, and suitability of habitats for elk--that is, it is a biologically based index. This index reflects elk-habitat effectiveness during a period of the year when elk are not hunted. Habitat management to enhance the hunting experience, to reduce the number of elk killed or the rate of elk killed during hunting season, or to benefit other wildlife are different issues and not addressed here.

Where the management objective is to give elk some degree of protection from hunters to enhance the difficulty of hunting or to spread the kill over a longer season (thereby providing more days of hunting recreation) or both, or to improve the welfare of animals dependent on old-growth forest stands, increasing the cover component appreciably would be desirable.

Literature Cited

Anderson, E.W.; Scherzinger, R.J. 1975. Improving quality of winter forage for elk by cattle grazing. Journal of Range Management. 28: 120-125.

Aune, K.E. 1981. Impacts of winter recreationists on wildlife in a portion of Yellowstone National Park, Wyoming. Bozeman, MT: Montana State University. 111 p. M.S. thesis.

Austin, D.D.; Urness, P.J. 1983. Overwinter forage selection by mule deer on seeded big sagebrush-grass range. Journal of Wildlife Management. 47(4): 1203-1207.

Austin, D.D.; Urness, P.J.; Fierro, L.C. 1983. Spring livestock grazing affects crested wheatgrass regrowth and winter use by mule deer. Journal of Range Management. 36(5): 589-593.

Bayoumi, M.A.; Smith, A.S. 1976. Response of big game winter range vegetation to fertilization. Journal of Range Management. 29: 44-48.

Beall, Robert C. 1976. Elk habitat selection in relation to thermal radiation. In: Hieb, S.R., ed. Elk-logging-roads: Proceedings of a symposium. Moscow, ID: University of Idaho: 97-100.

Black, H., Jr.; Scherzinger, R.; Thomas, J.W. 1976. Relationships of Rocky Mountain elk and Rocky Mountain mule deer to timber management in the Blue Mountains of Oregon and Washington. In: Hieb, S.R., ed. Elk-logging-roads: Proceedings of a symposium. Moscow, ID: University of Idaho: 11-31.

Collins, W.B. 1977. Diet composition and activities of elk on different habitat segments in the lodgepole pine type, Uinta Mountains, Utah. Logan, UT: Utah State University. 74 p. M.S. thesis.

Collins, W.B.; Urness, P.J. 1979. Elk pellet group distribution and rates of deposition in aspen and lodgepole pine habitats. In: Boyce, M.S.; Hayden-Wing, L.D., eds. North American elk: ecology, behavior and management. Laramie, WY: University of Wyoming: 140-144.

Compton, T. 1975. Mule deer-elk relationships in the western Sierra Madre area of south-central Wyoming. Wildl. Tech. Rep. 1. Cheyenne, WY: Wyoming Fish and Game Department. 125 p.

Cupal, J.J.; Ward, A.L. 1976. Telemetered heart rate of two elk as affected by activity and human disturbance. Unpublished. Laramie, WY: U.S. Department of Agriculture, Forest Service, Forestry Sciences Laboratory.

Dell, J.D. 1980. Guidelines for predicting fire effects on forest and range resources in Region 6. R6 - A&FM - 058 - 1981. Portland, OR: U.S. Department of Agriculture, Forest Service. 22 p.

Gates, C.C.; Hudson, R.J. 1981a. Habitat selection by wapiti in a boreal forest enclosure. Naturaliste Canada. 108: 153-166.

Gates, C.C.; Hudson, R.J. 1981b. Weight dynamics of wapiti in the boreal forest. Acta Theriologica. 26.27: 407-418.

Gavin, T.A.; Suring, L.H.; Vohs, P.A., Jr.; Meslow, E.C. 1984. Population characteristics, spatial organization, and natural mortality in the Columbian white-tailed deer. Wildlife Monograph. 91.41 p.

Geist, V. 1982. Adaptive behavioral strategies. In: Thomas, Jack Ward; Toweill, Dale E., eds. Elk of North America-ecology and management. Harrisburg, PA: Stackpole Books: 219-277.

Gruell, G.E. 1980. Fires influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Res. Pap. INT-252. 2 vols. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 242 p.

Hall, F.C. 1973. Plant communities of the Blue Mountains in eastern Oregon and Washington. R6 Area Guide 3-1. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 62 p.

Hall, F.C. 1977. Ecology of natural underburning in the Blue Mountains of Oregon. R6 - ECOL - 79 - 001. Portland, OR: U.S. Department of Agriculture, Forest Service. 11 p.

Hobbs, N.T.; Baker, D.L.; Ellis, J.E.; Swift, D.M.; Green, R.A. 1982. Energy and nitrogen-based estimates of elk winter-range carrying capacity. Journal of Wildlife Management. 46(1): 12-21.

Hobbs, N.T.; Spowart, R.A. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. Journal of Wildlife Management. 48(2): 551-560.

Hobbs, N.T.; Swift, D.M. 1985. Estimates of habitat carrying capacity incorporating explicit nutritional constraints. Journal of Wildlife Management. 49(3): 814-822.

Holl, S.A.; Salwasser, H.; Browning, B. 1979. The diet composition and energy reserves of California mule deer during pregnancy. California Fish and Game. 65(2): 68-79.

Hopkins, W.E.; Kovalchik, B.L. 1983. Plant associations of the Crooked River National Grassland. R6 Ecol. 133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 98 p.

Houston, D.B. 1982. The northern Yellowstone elk-ecology and management. New York: MacMillan Publishing Company. 474 p.

Isaacson, D.L.; Leckenby, D.A.; Alexander, C.J. 1982. The use of large-scale aerial photography for interpreting Landsat digital data in an elk habitat-analysis project. Journal of Applied Photographic Engineering. 8: 51-57.

Johnson, C.G.; Simon, S.A. 1985. Plant associations of the Wallowa Valley Ranger District, Part II: Steppe. Baker, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest. 103 p. + 4 appendixes.

Klemmedson, J.O. 1967. Big game winter range - a diminishing resource. Transactions of North American Wildlife and Natural Resources Conference. 32: 259-269.

Leckenby, D.A. 1979. Elk cover and forage inventory via satellite and computer. Oregon Lands. Vols. 3 (p. 2-3) and 4 (p. 2-2).

Leckenby, D.A. 1984. Elk use and availability of cover and forage habitat components in the Blue Mountains, northeast Oregon 1976-1982. Wildl. Res. Rep. 14. Portland, OR: Oregon Department of Fish and Wildlife. 40 p.

Leckenby, D.A.; Isaacson, D.L.; Thomas, S.R. 1985. Landsat application to elk habitat management in northeast Oregon. The Wildlife Society Bulletin. 13(2): 130-134.

Lyon, L.J. 1979. Influences of logging and weather on elk distribution in western Montana. Res. Pap. INT-236. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 11 p.

Lyon, L.J. 1980. Coordinating forestry and elk management. Transactions of North American Wildlife and Natural Resources Conference. 45: 278-287.

Lyon, L.J. 1983. Road density models describing habitat effectiveness for elk. Journal of Forestry. 81(9): 592-595, 613.

Marcum, C.L. 1976. Habitat selection and use during summer and fall months by a western Montana elk herd. In: Hieb, S.R., ed. Elk-logging-roads: Proceedings of a symposium. Moscow, ID: University of Idaho: 91-96.

McConnell, B.R.; Smith, J.G. 1970. Response of understory vegetation to ponderosa pine thinnings in eastern Washington. Journal of Range Management. 23(3): 208-212.

Medcraft, J.R.; Clark, W.R. 1986. Big game habitat use and diets on a surface mine in northeastern Wyoming. Journal of Wildlife Management. 50(1): 135-142.

Miller, R.F.; Vavra, Martin. 1981. Deer, elk, and cattle diets on northeastern Oregon rangelands. In: Proceedings of the wildlife-livestock relationships symposium. Coeur d'Alene, ID. Moscow, ID: University of Idaho: 500-508.

Moen, A. 1973. Wildlife ecology, an analytical approach. San Francisco, CA: W.H. Freeman and Company. 458 p.

Morgantini, L.E.; Hudson, R.J. 1979. Human disturbance and habitat selection in elk. In: Boyce, M.S.; Hayden-Wing, L.D., eds. North American elk: ecology, behavior and management. Laramie, WY: University of Wyoming: 132-139.

Murray, R.; Leckenby, D.A. 1985. Elk habitat evaluation using distance-mapped Landsat data. In: Proceedings from Pecara 10, remote sensing in forest and range resource management, 20-22 August 1985, Fort Collins, CO. Falls Church, VA: American Society of Photogrammetry and Remote Sensing: 346-355.

Nelson, J.R.; Leege, T.A. 1982. Nutritional requirements and food habits. In: Thomas, Jack Ward; Toweill, Dale, eds. Elk of North America-ecology and management. Harrisburg, PA: Stackpole Books: 323-369.

Parker, K.L.; Robbins, C.T. 1984. Thermoregulation in mule deer and elk. Canadian Journal of Zoology. 62: 1409-1422.

Parker, K.L.; Robbins, C.T.; Hanley, T.A. 1984. Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management. 48(2): 474-488.

Pedersen, R.J.; Adams, A.W.; Skovlin, J. 1979. Elk management in Blue Mountain habitats. A report of the Research and Development Section. Portland, OR: Oregon Department of Fish and Wildlife. 27 p.

Pedersen, R.J.; Adams, A.W.; Skovlin, J.M. 1980. Elk habitat use in an unlogged and logged forest environment. Res. Rep. 9. Portland, OR: Oregon Department of Fish and Wildlife. 121 p.

Peek, J.M.; Scott, M.D. Nelson; L.J.; Peirce, D.J.; Irwin, L.L. 1982. The role of cover in habitat management in Northwestern United States. Transactions, North American Wildlife Natural Resources Conference. 47: 363-373.

Perry, C.; Overly, R. 1977. Impacts of roads on big game distribution in portions of the Blue Mountains of Washington, 1972-1973. Appl. Res. Sect. Bull. 11. Olympia, WA: Washington Game Department. 39 p.

Pitt, M.D. 1986. Assessment of spring defoliation to improve fall forage quality of bluebunch wheatgrass (*Agropyron spicatum*). Journal of Range Management. 39(2): 175-181.

Richens, J.B.; Lavigne, G.R. 1978. Response of white-tailed deer to snowmobiles and snowmobile trails in Maine. Canadian Field-Naturalist. 92: 334-344.

Robbins, C.T. 1983. Wildlife feeding and nutrition. New York: Academic Press. 343 p.

Robinette, W.L.; Baer, C.H.; Pilmore, R.E.; Knittle, C.E. 1973. Effects of nutritional change on captive mule deer. Journal of Wildlife Management. 37(3): 312-326.

Rost, G.R.; Bailey, J.A. 1974. Responses of deer and elk to roads on the Roosevelt National Forest. Proceedings, The Wildlife Society Meeting, Northwest Section, Edmonton, AB. Northwest Section, The Wildlife Society: 52-62.

Severinghaus, C.W.; Tullar, B.F. 1975. Wintering deer versus snowmobiles. Conservationist. 29(6): 31.

Skovlin, J.M.; Edgerton, P.J.; McConnell, B.R. 1983. Elk use of winter range as affected by cattle grazing, fertilizing, and burning in southeastern Washington. Journal of Range Management. 36(2): 184-189.

Svejacr, T.; Vavra, M. 1985. The influence of several range improvements on estimated carrying capacity and potential beef production. Journal of Range Management. 38(5): 395-399.

Thomas, J.W.; Black, H., Jr.; Scherzinger, R.J.; Pedersen, R.J. 1979. Deer and elk. In: Thomas, J.W., ed. Wildlife habitats in managed forests-the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture: 104-127.

U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. 103 ESM Release 1-81.Washington, DC: Division of Ecological Service, U.S. Department of the Interior. 150 p.

Urness, P.J.; Austin, D.D.; Fierro, L.C. 1983. Nutritional value of crested wheatgrass for wintering mule deer. Journal of Range Management. 36(2): 225-226.

Ward, A.L.; Cupal, J.J.; Goodwin, G.A.; Morris, H.D. 1976. Effects of highway construction and use on big game populations. Final Rep. FHWA-rd-76-174. Springfield, VA: National Technical Information Service. 88 p.

Ward, A.L.; Fornwalt, N.E.; Henry, S.E.; Hodorff, R.A. 1980. Effects of highway operation practices and facilities on elk, mule deer, and pronghorn antelope. Rep. FHWA--79-143. Washington, DC: Research and Development, Federal Highway Administration, U.S. Department of Transportation. 48 p.

Wickstrom, M.L.; Robbins, C.T.; Hanley, T.A.; Spalinger, D.E.; Parish, S.M. 1984. Food intake and foraging energetics of elk and mule deer. Journal of Wildlife Management. 48(4): 1285-1301.

Willms, W.; Bailey, A.W.; McLean, A.; Tucker, R. 1980. The effects of fall grazing and burning bluebunch wheatgrass range on forage selection by deer and cattle in spring. Canadian Journal of Animal Science. 80: 113-122.

Willms, W.; Bailey, A.W.; McLean, A.; Tucker, R. 1981. The effects of fall defoliation on the utilization of bluebunch wheatgrass and its influence on the distribution of deer in spring. Journal of Range Management. 34: 16-18.

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An elk habitat evaluation procedure for winter ranges in the Blue Mountains of eastern Oregon and Washington is described. The index is based on an interaction of size and spacing of cover and forage areas, roads open to traffic per unit of area, cover quality, and quantity and quality of forage.

Keywords: Winter range, wildlife habitat, elk, Oregon (Blue Mountains), Blue Mountains--Oregon, Washington (Blue Mountains), Blue Mountains--Washington.

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