Elk Hiding and Thermal Cover Guidelines in the Context of Lodgepole Pine Stand Density[1]

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ABSTRACT. We present a technique to evaluate how ungulate hiding and thermal cover guidelines affect density management of lodgepole pine (Pinus contorta) *stands. Modification of a lodgepole pine density management diagram results in a graphical tool useful to forest managers interested in wildlife habitat evaluation. This technique can be used to determine the amounts of cover provided by silvicultural prescriptions and to evaluate cover status of existing stands. Stand structures that meet the guidelines were determined by simulation modeling and field sampling. Current hiding cover requirements were met when summed dbh was above about 5,000 in./ac or when summed crown diameters were greater than 630 ft/ac. The thermal cover requirement was determined to be the most restrictive element of the guidelines.*

West. J. Appl. For. 2:6–10, January 1987.

Cover provided by stands of coniferous trees is an important component of the habitat of elk (*Cervus elaphus nelsonii*) and mule deer (*Odocoileus hemionus hemionus*) in the Rocky Mountains and Intermountain West. Wildlife biologists typically characterize cover as either thermal or hiding cover, although the two concepts are not mutually exclusive (Peek et al. 1982). Thermal cover provides protection from extreme heat or cold and is assumed to minimize the energy required for thermoregulation by the animals. Hiding cover is assumed to provide real or perceived security from predators, including humans (Black et al. 1976).

After reviewing a fairly extensive literature on the subject, Peek et al. (1982) conclude that there are still substantial gaps in our understanding of the influence of cover on big game. For example, most assessments of optimum habitat are based on studies of use patterns, by direct observation, telemetry, or pellet surveys, rather than an animal's physiological response to its environment. While they are important sources of information, habitat use patterns may not distinguish between habitat preferences and actual requirements (Peek et al. 1982). Another important determinant of optimum habitat is how components of that habitat are distributed. For example, Black et al. (1976) propose that cover and forage habitat be maintained in a 40%–60% mix.

However, an even more pressing problem is how to translate existing cover guidelines into quantified expressions of stand structure. Silviculturists must have unambiguous translations of hiding and thermal cover and guidelines that help them assess cover status for individual stands based on easily measured and understood stand structure characteristics. This basic aspect of habitat management has received surprisingly little attention (Cole 1983; Dealy 1985).

In this paper we describe how we translated hiding and thermal cover guidelines into stand structure characteristics and, ultimately, into a silvicultural tool to implement those guidelines. We briefly describe the development and validation of a computer model that predicts hiding and thermal cover from appropriate stand characteristics. The model is then used to modify a lodgepole pine density management diagram (McCarter and Long 1986), resulting in a tool to help assess cover for particular stands or evaluate cover under alternative stand management strategies.

METHODS

We developed a simulation model to predict how much of an elk or mule deer would be hidden in lodgepole pine stands. The model is based on stand structural variables including tree sizes, density and spatial distribution. The amount of hiding cover provided by a specific stand, interpreted under conditions specified in the wildlife management literature (e.g , Thomas et al. 1979), is largely a trigonometric problem. Tree boles are solid and will hide an arc whose length is proportional to the diameter at breast height (dbh) of the tree, the distance between the tree and the observer, and the distance from the observer to the arc. How much of an arc (or elk) will be hidden is determined by the number, size, and position of trees between the observer and the arc. Since tree crowns are not completely solid, more than one crown is necessary to completely hide an arc segment from a viewer. Therefore, a relationship accounts for the partial transparency of crowns where the bases of live crowns in a stand were below the body of a simulated elk. The model also predicts thermal cover provided by stands based on the relation between canopy cover and density.

The model first places trees on a representative 1 ac grid and then samples the amount of an arc hidden at a given distance. A stand is generated from a user-specified quadratic mean dbh (Dq), number of trees per acre (tpa), and spatial arrangement Individual tree dbh are randomly assigned from a normal distribution with a standard deviation of 20% of the mean diameter. The user specifies whether trees are placed in the 1 ac grid randomly, regularly, or in a clumped distribution. Regular spacing is defined as one tree randomly located within a separate rectangle; the area of each is inversely proportional to the number of trees per acre Clumped distributions are defined by the maximum clump size and the number of clumps per acre.

After generating the stand, a sampling procedure determines the proportion of an arc segment hidden at a given distance. The arc segment is defined as 6 ft in length, about as long as the body of an elk. Sampling is necessary given the inherent variability in coverage by trees. This variability in tree coverage is somewhat analogous to a solid fence with one small hole At one point in the fence (the hole), 100% of the elk is visible while at all other points the elk is completely hidden. At any viewing position the angle subtended by each tree depends on its distance from the viewing posi-

[1] The help of James McCarter, Reese Pope, Frank Cross, and Bob Thompson is appreciated. This study was supported by the USDA Forest Service Rocky Mountain Region Office of Timber, Forest Pest and Cooperative Forest Management. This paper is printed with the approval of the Utah Agricultural Experiment Station, Utah State University, 84322-4810, Journal Paper No. 3253.

tion and its dbh This angle is then projected to the arc at the sighting distance, and absolute coordinates of the hidden arc segment are determined. The absolute coordinates of the arc hidden by each tree are compared to the absolute coordinates of 100 0.6-ft intervals of the arc segment representing the elk. The amount of the elk hidden is the ratio of hidden intervals to the total arc segment representing the elk. This process is repeated at the specified number of viewing positions evenly spaced along one side of the acre stand. The mean of the observations represents the average elk hiding cover.

If the average base of the live crowns for the stand is below 3 ft, crowns are considered to contribute to hiding cover. Base of the live crown is determined from a relation between live crown ratio and stand density index (SDI) (Reineke 1933, Daniel et al 1979, Long 1985). The stand in this case is defined from the average height, number of stems, and spatial arrangement. Individual tree heights are normally distributed with a standard deviation of 20% of the mean height. Tree dbh is determined from a relation between height and dbh, and crown diameter from a relation between dbh and crown diameter. Individual trees may be placed in the acre randomly, regularly or in a clumped fashion. Sampling occurs as for tree boles except for the correction for partial transparency of tree crowns. The number of crowns that hide each of the 100 intervals of the arc segment representing the elk are totaled, and the portion of each interval hidden is determined from the sight extinction relationship.

Data collected on the Medicine Bow National Forest in Wyoming were used to develop empirical relations for the model and to validate model results. Thirty stands were measured, 15 where only boles contributed to hiding cover and 15 where crowns contributed to hiding cover. Bole stands included a range of Dq (3.0 to 14.2), density (153 to 3398 tpa), and were sampled with 5 variable plots. Standard mensurational data were determined for trees in each plot. In addition, canopy cover was estimated with a spherical densiometer (Lemmon 1956), and the relationship between canopy cover and SDI was determined (Table 1).

Crown stands included a range of mean height (7 to 28 ft) and density (124 to 1997 tpa) and were sampled with 5 fixed area plots. Standard mensurational data including live crown length and crown diameter were determined for each tree. The relations between dbh and height, and crown diameter and dbh for individual trees were determined from these data (Table 1). The average height of the bases of live crowns was determined from the relation between live crown ratio and percentage of maximum SDI (Table 1). Maximum SDI for lodgepole pine was taken as 700 (McCarter and Long 1986).

Elk hiding cover was determined in each of the 30 stands. Two parallel 200-ft lines were established 200 ft from each other. A sighting target 6 ft long and 3 ft high centered 4.5 ft above the ground was used to simulate the body of an elk. The target was divided into 98 equal-sized squares of alternating color. An observer standing on one line with the target positioned 200 ft away on the second line counted the number of visible squares. Twenty sightings were taken at even intervals along the 200-ft lines. Counts were converted to percentage of the target hidden at each point and then used to determine an average percentage of the target hidden in the stand.

To collect data used to estimate the relative "transparency" of lodgepole pine crowns, 30 sets of three trees on a line were selected. The base of the live crowns were below 3 ft. The proportion of the target hidden by trees was determined for each set with 1, 2, and 3 trees between the observer and the target. As the number of tree crowns between the viewer and the elk increased from 1 to 3, the average amount of the target hidden was 58, 84, and 95%, respectively.

Table 1. Regression statistics for species-specific relations used in the model.

Y	X	Equation	R^2	n	S.E.
Canopy cover (%)	SDI	$Y = 5.41 + 0.177X$	0.79	15	10.6
dbh (in.)	Height (ft)	$Y = 1.136 + 0.279X$	0.94	405	0.45
Crown diameter (ft)	DBH (in.)	$Y = 1.225 + 1.465X$	0.87	405	1.01
Live crown ratio (%)	% Maximum SDI	$Y = 98.07 - 0.510X - 0.006X^2$	0.92	59	0.7%

RESULTS

The model was used to evaluate the relation between hiding and thermal cover (Thomas et al. 1979) and stand structure. Current guidelines state that summer thermal cover is provided when canopy closure equals or exceeds 70% and stand height is at least 40 ft. For lodgepole pine stands, 70% canopy closure corresponds to an SDI of 365 (Table 1).

We assumed that hiding cover was adequate when an average of 90% of an adult elk was hidden at a distance of 200 ft. Further, distribution of trees was assumed to be fairly regular, as in a natural, self-thinning stand or young, natural stand following an early density adjustment. Fifty observation points were established in each simulated stand, and three replications were run for each stand structure. Average hiding cover was determined for 103 stand structures where boles provided hiding cover and 53

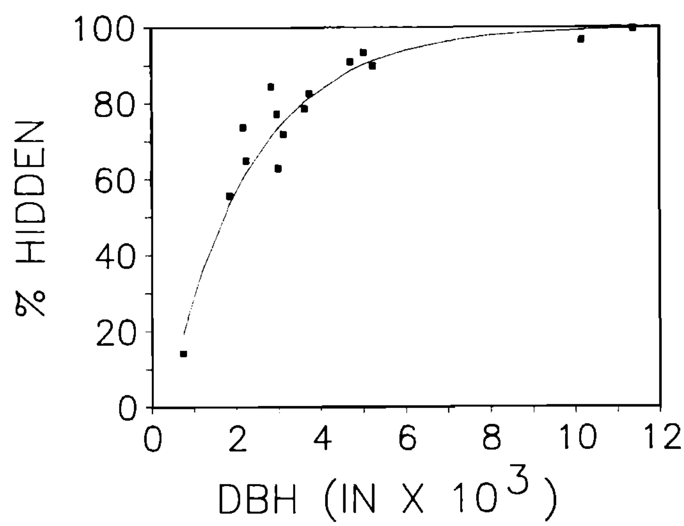

Fig. 1. The relationship between average hiding cover and the sum of dbh for 15 samples stands [■] and for the simulation model (solid line) where boles alone provide cover.

stands where crowns provided hiding cover. Stand density index ranged from 25 to 700 and Dq ranged from 5 to 15 in. for these simulated bole stands. Average height ranged from 8 to 32 ft and density ranged from 50 to 500 stems/ac for the crown stands.

Model results indicated that there was a well-defined relationship between the amount of an elk hidden and the sum of the dbh of trees in stands where the live crown was above 3 ft:

$$Y = 100.0 - 115.8 \cdot 0.61^{X}$$

where

Y is the percent of the elk hidden

X is the sum of the dbh in in./1000

$R^2 = 0.98$

To provide the threshold value of 90% hiding cover, the sum of the dbh for a stand must be 4979 in. or greater.

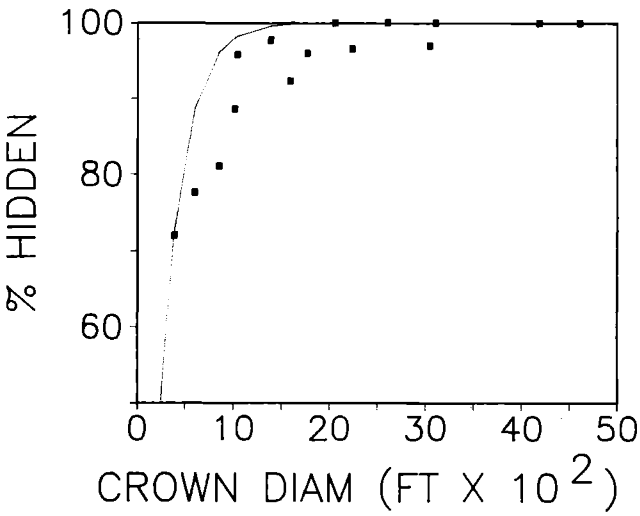

Fig. 2. The relation between average hiding cover and the sum of crown diameters for 15 sampled stands [■] and for the simulation model (solid line) where tree crowns provide cover.

Similar results were predicted when the model simulated stands where the base of the live crowns were below 3 ft. Hiding cover was related to the sum of the crown diameters for trees in a stand by:

$$Y = 100.0 - 142.0 \cdot 0.66^{X}$$

where

Y is the percent of the elk hidden

X is the sum of the crown diameters in ft/100

$R^2 = 0.97$

To provide the threshold value of 90% hiding cover, the sum of the crown diameters must be at least 630 ft/ac. As with the bole stands, a regular spatial arrangement was specified. Much higher stand densities were required to provide hiding cover when random or clump distributions were simulated.

Results based on simulated stands were compared to field estimates of elk hiding cover to validate model predictions. In Figure 1, the measured average hiding cover was plotted against the sum of the dbh for sampled stands. The relationship for simulated stands is the solid line. There is good agreement between predicted and observed results. Variation may

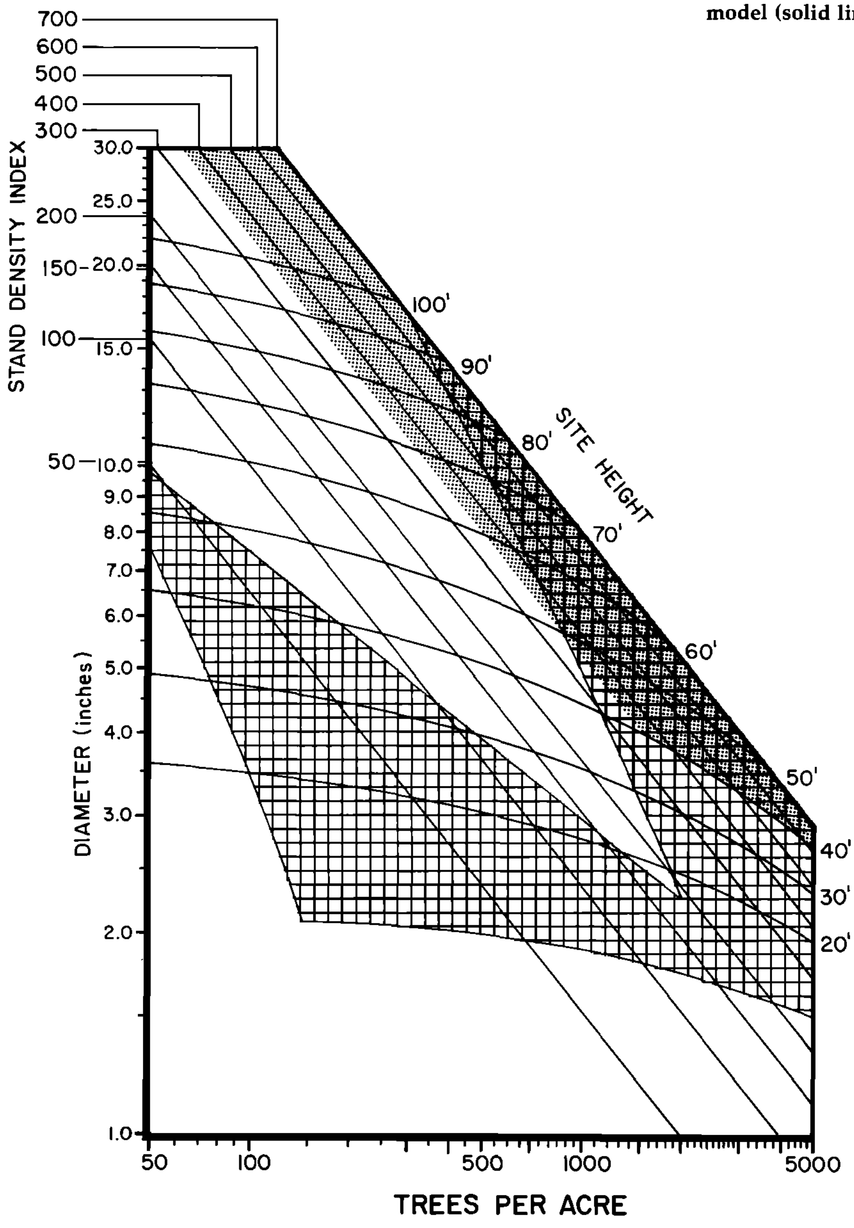

Fig. 3. Evaluation of hiding and thermal cover guidelines by delineating regions that meet guidelines on the density management diagram of McCarter and Long (1986). Regions of tpa and Dq which meet or exceed guidelines are shown for hiding cover (#) and thermal cover (░). An 8½ by 11 in. copy of this diagram may be obtained from the authors.

reflect the fact that there were fewer sighting targets in field observations (20 per stand) than in the simulation (50 per stand). Observed hiding cover did not agree with simulated results for stands where the base of the live crown is beneath 3 ft (Figure 2). The results of the simulation form an upper boundary line with respect to the results of field sampling, perhaps due to differences in the arrangement of trees in the simulations and field samples. There were few sapling stands with hiding cover below 90%, and these stands tended to be irregularly spaced. When the spatial arrangement is clumpy, a higher density of trees is necessary to provide the same hiding cover as a more regularly spaced stand. Clumps typically have "excess" trees while few trees are present between clumps to obscure a line of sight The results presented here apply to stands with a somewhat regular spatial arrangement, which might occur naturally or as a result of thinning.

DISCUSSION

The model enables us to determine those stand structures (e.g., combinations of Dq and tpa), which meet certain criteria for hiding or thermal cover. Stand structures that do or do not meet the specified criteria can then be graphically displayed. Figure 3, for example, represents an evaluation of the current hiding and thermal cover guidelines. Any modification of these guidelines (e.g. if the minimum sight distance for hiding cover was reduced from 200 ft to 150 ft), would change the figure (in this case, a "shrinking" of the hiding cover area)

The stand structure/cover diagram (Figure 3) is useful in evaluating the cover characteristics of a particular stand. For example, the diagram suggests that a young lodgepole pine stand with 1450 tpa and a Dq of 1.0 in. does not provide sufficient hiding cover to meet the guidelines (Figure 3).

Stand structure is, of course, dynamic; it changes in predictable ways. Average height, dbh, and crown size all increase as trees grow. As the combination of average size and density reaches a threshold level, lower branches begin to die, and crowns begin to lift. Eventually self-thinning, or suppression mortality, may reduce the number of trees per acre.

As the structure of a stand changes with time, so do its cover characteristics. The stand structure/cover diagram can be used to predict and plan for these changes. An estimate of average dominant tree height (HTs) together with the site index allow us to estimate stand age (McCarter and Long 1986). For example, if HTs for a stand were 50 ft and the site index (base age 100) was 70 ft, we would predict that the stand was about 59 years old (Alexander et al. 1966).

To illustrate use of the diagram, we will evaluate how two alternative hypothetical management strategies affect cover in the example lodgepole pine stand. Remember that neither "strategy" represents a management recommendation. Alternative A (Figure 4) represents a "no-thinning" option; the stand is allowed to grow, unthinned, until it is about 100 years old (i.e., SI(100) = 70 ft, HTs = 65 ft). Using the estimates of HTs and the appropriate site index curve, we estimate the ages at which the stand moves in and out of various cover categories (Table 2). For example, when the stand has a HTs of 7 ft (10 years of age), it begins to provide hiding cover; however, when HTs reaches 20 ft (20 years of age), the crowns have lifted enough to reduce hiding cover. Eventually the combination of tpa and Dq in this unmanaged stand is sufficiently great that the crown-free boles meet the criterion for hiding cover. When HTs reaches 40 feet and canopy cover is greater than or equal to 70%, the stand also meets the criteria for summer thermal cover. In Regime A, hiding cover is provided for 74 years by boles and crowns, and thermal cover requirements are met during the last 50 years of the rotation (Table 2). It is questionable, however, whether large animals would actually use a stand of this extreme density (i.e., about 1400 tpa and Dq = 4.2 in. when the thermal cover guidelines are first met).

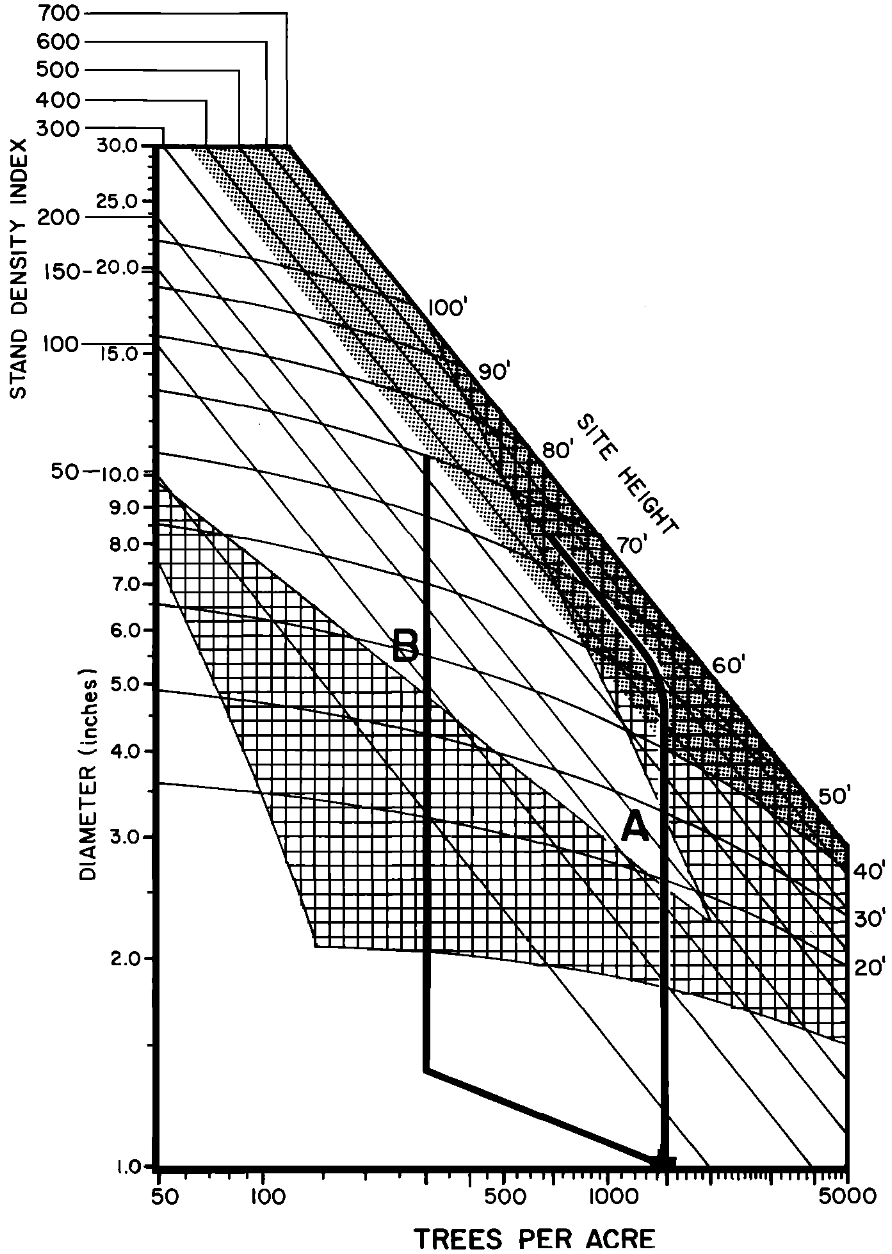

Fig. 4. Comparison of hiding and thermal cover provided by two hypothetical density management regimes. Regime A is an unmanaged stand with 1450 spa and Regime B is the same stand thinned to 300 spa in an early density adjustment.

Table 2. Comparison of hiding and thermal cover provided by Regime A and Regime B.

	Crown hiding cover Age			Bole hiding cover Age			Thermal cover Age		
	Start	End	Yr	Start	End	Yr	Start	End	Yr
Regime A	10	17	7	33	100	67	50	100	50
Regime B	10	34	24	—	—	0	—	—	0

Stand structure and the associated cover can be manipulated. Alternative B (Figure 4) represents one of many possible thinning options. The stand is precommercially thinned to approximately 300 tpa to produce a Dq of 10.8 in. in a 100-year rotation. As soon as HTs reaches 7 ft, the stand meets the hiding cover criteria. At this relatively low density, self-pruning is delayed and thus the base of the live crowns remain below 3 ft until HTs is 33 ft. This thinning option, therefore, provides hiding cover sufficient to meet the guidelines for approximately 24 years (i.e., from 10 to 34 years of age) or about 24% of the rotation (Table 2).

Wildlife biologists should, and in many cases do, work with silviculturists to improve quality ungulate habitat. Cover guidelines have important implications for wildlife and for other forest resources. Even minor changes in these guidelines would have substantial impact on the density management of stands, a fact that clearly indicates the need for definitive research on ungulate cover requirements.

There are several basic conclusions concerning this analysis of stand structure and cover. First, the nature of lodgepole pine crown development means that the current summer thermal cover guidelines are exceedingly restrictive. Slow growth, reduced vigor, and increased susceptibility to catastrophic loss to mountain pine beetles are characteristics of lodgepole pine stands with SDIs greater than 365 (Long 1985). Therefore, it is critical that the relation between lodgepole pine canopy closure and ungulate habitat requirements be precisely defined. Second, mature stands, those in which crowns have lifted and only boles provide screening, do not effectively provide hiding cover. Finally, however, young "crown" stands, even those with surprisingly low densities, provide very good hiding cover. An effective management strategy in areas were hiding cover may be limiting would be to convert mature stands to young ones through harvest and regeneration For maximum benefit, young stands should also be thinned early to maintain low crowns for an extended period of time. □

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Early Career Development of Foresters, Range Conservationists, and Wildlife/Fisheries Biologists in Two Western Forest Service Regions[1]

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ABSTRACT. This paper examines how newly hired foresters are adapting to their profession and a career in the Forest Service in comparison to their range conservationist and wildlife/fisheries biologist colleagues. The sample consisted of 44 foresters, 27 range conservationists, and 38 biologists with 1–3 years permanent Forest Service employment in the Intermountain and Pacific Northwest regions, as well as 35 of their immediate supervisors. About half the sample were women.

Most young recruits have found satisfying careers both in their profession and within the Forest Service. Foresters and range conservationists seemed to more readily accept organizational values and develop a long-term commitment to the Forest Service than did their biologist colleagues. Some women had difficulty adapting to their professions and to the Forest Service.

The professional and sexual diversity of these new types of recruits has implications for their integration into the Forest Service, acceptance of their values and loyalties, and the evolution of a natural resources agency traditionally dominated by male foresters.

West. J. Appl. For. 2:10–14, January 1987

In its first 50 years, the USDA Forest Service (FS) was a cohesive and effective professional organization of male foresters (Gulick 1951, Kaufman 1960) However, the social and political changes of the 1970s have made the FS a more diverse agency. The FS recruits studied in this paper reflect this new era, in that 41% of the professional land managers hired by the Intermountain and Pacific Northwest Re-

[1] Support for this work was provided by the Utah Agricultural Experiment Station, Utah State University, Logan in cooperation with the USDA Forest Service (Journal Paper 3027).