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MANAGEMENT IMPLICATIONS OF ELK AND DEER USE OF CLEAR-CUTS IN MONTANA

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Abstract: Elk (*Cervus elaphus nelsoni*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*O. virginianus*) pellet-group densities were counted in and adjacent to 87 clear-cuts of various sizes and ages in eastern and western Montana. Pellet distributions suggest that animals enter clear-cut openings in search of better quality or greater quantities of forage. However, the willingness of animals to enter an opening is influenced by a requirement for security during the feeding period and is locally modified by the past experiences of animals in the available environment. Both elk and deer preferred clear-cuts with cover in the opening except where such cover inhibited forage growth. Both preferred openings in which logging slash was not a barrier to movement. Elk preferred smaller openings than deer, but were more tolerant of large openings—particularly where natural openings were already present in the environment. Elk use of clear-cuts was severely depressed by the presence of open roads and inadequate cover at the edge of the opening.

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For almost as many years as foresters have been prescribing clear-cuts, wildlife biologists have been evaluating the effects of those clear-cuts on big game. Clear-cut openings have been declared beneficial because they generally increase forage production and edge (Krefting 1962, Pengelly 1963, Reynolds 1966, Pearson 1968, Wallmo 1969, Basile and Jensen 1971, Harper 1971, and many others). However, clear-cutting has been declared detrimental because it reduces available cover and produces slash, thus increasing big game vulnerability to hunting and harassment, while actually reducing forage availability (Lyon 1971, 1976; Pengelly 1972; Garrison and Smith 1974; Beall 1976; Hershey and Leege 1976; Marcum 1976).

Either judgment is equivocal, and because clear-cutting is a sound silvicultural technique likely to receive continued use, a substantial number of investigators have attempted to determine the size and age of openings best suited to use by big game. Reynolds (1962*a*, 1966, 1969) reported a series of studies in which pellet-group distributions were used as indicators of deer and elk preferences. He concluded that 18 ha for elk and 14 ha for deer in ponderosa pine types and 9 ha in spruce-fir types probably represent the maximum size openings that will be fully utilized by animals. Other investigators (Miller 1974, Lyon 1976) have confirmed that openings larger than 16 ha are used less than smaller openings, but there are also numerous observations of elk using very large open parks and hillsides (Murie 1951, Anderson 1958, Boyd 1970, Ward 1973), and many mule deer ranges have no significant component of forest cover (Robinette 1966, Mackie 1970, Urness 1976). There are even white-tailed deer habitats described in the literature (Teer et al. 1965, Allen 1968) that have considerable proportions of open area.

The expected time frame for increased forage production also has a high degree of variability. Reynolds (1962*b*) found that deer use of clear-cuts in ponderosa pine (*Pinus ponderosa*) was ⅓ lower than use of unlogged areas for the 1st 2 years and 7–8 times greater for the next 9 years. Harper (1971) reported that clear-cuts in Oregon reached peak production 5–8 years after logging, while Hanson and Smith (1970) suggested that timber harvest openings in forests of the eastern United States last 10–20 years. In Idaho, browse response to logging lasted 30–50 years (Pengelly 1972), and Lyon (1966) indicated that shrub dominance in the northern Rocky Mountains may continue from 10 to 100 years.

In view of the variability reported, it seems safe to conclude that big game use of clear-cuts will not be predictably consistent in all locations and habitats. As Pengelly (1972) pointed out, a clear-cut in a dense coastal forest might be beneficial while a similar one on a dry site in eastern Montana could prove to be harmful. Some patterns seem broadly consistent, but managers also require site-specific studies that will ensure recognition of conditions clearly beneficial or harmful to wildlife.

The studies reported here were initiated to describe elk, mule deer, and white-tailed deer use of clear-cuts in Montana. Replicated studies east and west of the Continental Divide were considered necessary because habitats available to animals are different and because feeding and herding characteristics of the elk populations were known to be different.

In western Montana, big game summer range is typically heavily forested and many of the forest types are characterized by strong development of seral-shrub understory communities. Winter ranges are usually open shrub-fields on low elevation southerly slopes, and there is often no clear separation from summer range. The distribution and size of winter range areas is such that individual herds of elk rarely exceed a few hundred animals. Both deer and elk in western Montana are classified as browsers, although elk use considerable amounts of grass when available.

Eastern Montana summer range also is forested, but many of the forest types lack a strong shrub component. Winter ranges are, in many instances, distant and clearly separated from summer range by a twice-yearly migration. Concentrations of elk on open-grassland winter ranges may number in the thousands. Deer concentrate on shrub-field winter ranges, but these areas often are distant from conifer tree cover and contain shrub species unlike those in communities with trees.

METHODS

During the summer of 1973, 49 clear-cuts on elk summer range in western Montana were examined to determine deer and elk use as indicated by pellet-group distributions. The sample included a range of clear-cut sizes, ages, slash treatments, forest types, and other independent variables (Table 1). In 1975, the study was repeated on 38 clear-cuts in eastern Montana. During both years, elk and deer pellet-groups were counted on 0.008-ha circular plots located at 30-m intervals along transects crossing the clear-cut opening and continuing 152 m into the surrounding uncut forest.

In the initial analyses, data were summarized to express the average elk and deer pellet-group densities inside and outside clear-cuts and at various distances from the edge. Conventional regression modeling techniques and analyses similar to those used by Reynolds (1962*a*, 1966, 1969) were applied to these data. The linear additive effects of all independent variables in all combinations were screened, by least squares fit, for strength of relation to elk and deer pellet counts. The analytic result was that accumulated information recovery leveled off with 3- to 5-variable models and at R^2 generally less than 0.40. Although highly significant in a statistical

Table 1. Means and ranges of selected variables recorded for clear-cuts west (49) and east (38) of the Continental Divide in Montana.

Variable	West		East	
	Mean	Range	Mean	Range
Area of clear-cut opening, ha	30	2–138	17	3–58
Perimeter of opening, km	2.8	0.7–11.2	1.8	0.6–3.8
Vegetation height in opening, m	0.9	0.1–2.4	0.8	0.3–2.5
Slash depth in opening, m	0.4	0.2–0.9	0.3	0.1–0.8
Cover quality—adjacent forest (scale 1–3)	2.1	1.3–2.9	1.9	1.1–2.7
Dead-and-down timber depth adjacent, m	0.5	0.3–0.8	0.4	0.2–0.9
Slope, %	34	10–70	17	0–75
Altitude, m	1,639	1,097–2,012	2,094	1,829–2,377
Elk pellet groups/ha in opening	67	0–288	91	0–330
in forest	106	0–751	145	3–463
Deer pellet groups/ha in opening	55	0–386	114	0–548
in forest	93	0–470	140	3–422

sense, these linear models were weak in explanatory power.

Linear additive models have a limited form potential for exploiting information contained in the data, and attention was next focused on curve forms and interactions that might logically be expected to exist. These were complex beyond reasonable preanalytic mathematical specification. So, subject to the constraints of expectation, graphic and related mathematical hypotheses were developed directly from the data following Jensen and Homeyer (1970, 1971) and Jensen (1973, 1976). Models developed in this way are a blend of accumulated prior knowledge and information extracted directly from the data. They represent the most advanced hypotheses as to the nature of the relations being investigated, but because models are developed directly from the data, probabilistic evaluation of components in the derived forms is sacrificed.

Objective statistical evaluation would require testing against additional data that are not available. However, some indication of the strengths of the relationships among variables is provided by fitting the models back on the data from which they were derived. The proportion of total sum of squares explained by each model can then be compared with the contrasting linear additive R^2.

For all 4 sets of available data, vegetation height in the opening, slash depths, and area of the opening were selected for initial examination. Other variables were added and some were deleted on the basis of visual inspection, until no further refinement of the models was expected. This analytic technique is subjective, and it is conceivable that different analysts could derive different models from the same data. Our experiences suggest, however, that wherever strong relationships exist, analysts will derive models of great similarity.

Models can be presented in both graphic representation and mathematical derivation, but the latter are of little utility without direct access to a computer. Accordingly, only the graphic models are presented in this paper. Readers interested in the mathematical derivations for

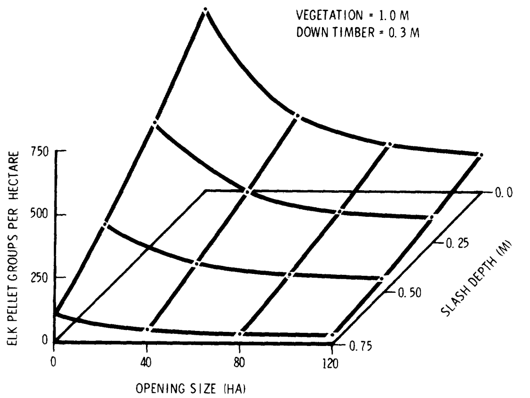

Fig. 1. Submodel for predicting elk pellet-group densities in clear-cuts, western Montana.

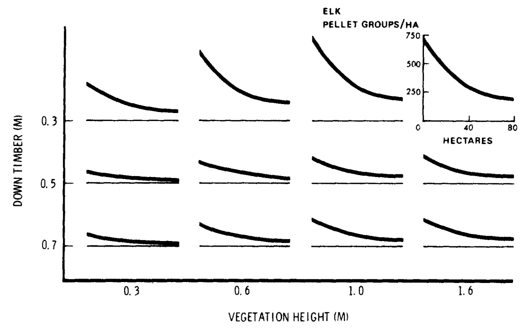

Fig. 2. Submodels for predicting elk pellet-group densities in clear-cuts, western Montana.

system applications may contact the authors.

Interpretation of these models is based on the assumption that pellet-group densities demonstrate the degree of willingness by animals to enter an opening. Some benefit is implied by the fact that pellet groups were present in clear-cuts at all, but ⅔ of the cuts examined had fewer pellet groups inside the opening than were found in the surrounding forest. Apparently, animals enter the openings to feed, but do not remain to ruminate. Thus, the study provides a description of those characteristics that make some clear-cuts more accessible than others.

RESULTS—ELK MODELS

Western Montana Elk

The model derived for predicting the density of elk pellet groups in western Montana clear-cuts includes 4 independent variables: vegetation height inside the opening, slash depth inside the opening, depth of dead-and-down timber in the adjacent forest, and area of the opening. R^2 for the model = 0.43, whereas for the linear additive effect of the same 4 variables, $R^2 = 0.26$.

Practical interpretation of a complex mathematical function is provided by the graphic model in Figs. 1 and 2. Figure 1 represents a submodel for situations in which vegetation height inside the opening is 1.0 m, and depth of dead-and-down timber in the adjacent forest averages 0.3 m. Within these constraints, the submodel represents a surface from which slash depth and area can be used to estimate the number of elk pellet groups/ha inside a clear-cut. For example, a clear-cut of 40 ha with slash 0.25 m deep would be expected to have 190 elk pellet groups/ha. The same clear-cut with 0.5 m of slash would have only 104 pellet groups/ha.

Additional submodels are required to show pellet densities for other combinations of vegetation height and depth of dead-and-down timber. However, if it is recognized that all submodels have about the same conformation, a representative set of submodels can easily be visualized from the curves for elk pellet densities at the back edge of each submodel (0.0 slash) over the range 0–80 ha (Fig. 2). Of the 4 variables used in generating this model, 2 (slash depth and area) are under the direct control of the forest manager, and a 3rd (vegetation height) is at least partially predictable as a function of management actions. The manager can pre-

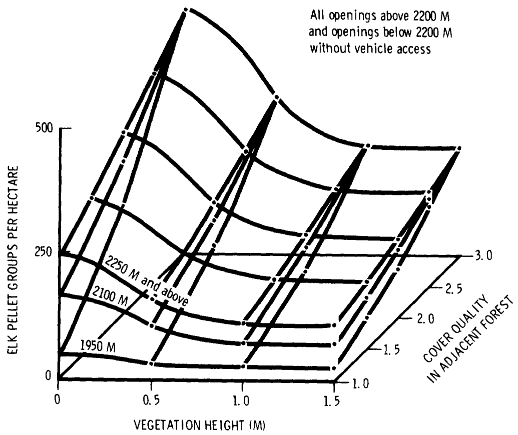

Fig. 3. Submodel for predicting elk pellet-group densities in clear-cuts, eastern Montana.

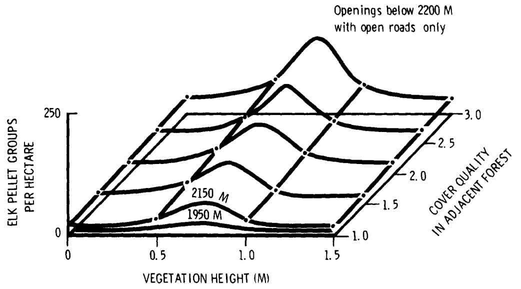

Fig. 4. Submodels for predicting elk pellet-group densities in clear-cuts, eastern Montana.

dict, for example, that elk will not fully utilize clear-cut areas until vegetation has developed to a height of at least 1 m.

It is not really possible to determine whether this is a cover requirement or simply a response to forage production as shrubs increase in height. Security appears to be a factor, however, because elk response to vegetation height is diminished substantially when the opening size exceeds 35 ha, slash inside the opening exceeds 0.5 m in depth, or dead-and-down timber in the adjacent forest reaches or exceeds 0.5 m in depth. Elk apparently prefer those situations in which they are able to move freely and are not required to move very far from forest cover.

Eastern Montana Elk

The model derived for predicting the density of elk pellet groups in eastern Montana clear-cuts includes 4 variables: elevation of the opening, cover quality of the uncut adjacent forest, vegetation height inside the opening, and vehicle access. Two of these variables involve subjective ratings on ordinal scales: *cover quality of adjacent forest,* 1 = poor cover where an animal in the survey plot could be readily observed at a distance of 100 m from at least 3 directions, 2 = fair cover where an animal in the survey plot could be observed at a distance of 100 m from 1 direction only, and 3 = good cover where an animal in the survey plot could not be observed at a distance of 100 m and would probably be hidden at 50 m; and *vehicle access,* 1 = vehicle traffic through the opening, 2 = vehicle access to edge of opening, and 3 = no vehicle access to opening. R^2 for the model = 0.75, whereas the linear additive effect of the same 4 variables yields R^2 = 0.65.

Graphic interpretation is supplied by Figs. 3 and 4. Figure 3 represents all clear-cut openings at or above 2,200 m, whether accessible to vehicles or not. Below 2,200 m, Fig. 4 applies to clear-cuts that have a road carrying through traffic while Fig. 3 continues to represent clear-cuts without through roads.

Of the 4 variables that contribute to the eastern Montana model, only vehicle access is under the immediate control of the land manager. Nevertheless, the model has some significant management implications, and when compared to the western Montana model, provides a considerable amount of information about elk behavior in relation to available environment.

One point that seems very clear is that security, or the lack of it, has a virtually overriding influence on the way elk are able to use these clear-cuts. The single most important variable in the model appears to be the binomial separation under which elk use of openings below 2,200 m is greatly reduced by the presence of an active road. However, despite the obvious split in our data, we believe that the relationship is less a function of elevation than a demonstration that forest roads above 2,200 m in our study area carry less traffic because of greater snowfall, less maintenance, and a high probability of termination at a clear-cut.

In clear-cuts where vehicular traffic does not prevent use by elk, the response to vegetation height in the opening is negative rather than positive as it was in western Montana. We view this as an exciting demonstration of consistency in elk behavior rather than an inconsistency in the models. The forest types sampled in eastern Montana largely consist of a grass-forb understory and a lodgepole pine (*Pinus contorta*) overstory, without a major shrub component. Vegetation height growth in a clear-cut consists almost entirely of trees, but ". . . lodgepole pine suppresses herbaceous plants while still in the seedling stage" (Basile 1975:253). In essence, forage growth, the characteristic of clear-cuts that induces elk to enter an opening, is inhibited by cover growth and the opening becomes less attractive even though cover quality increases. Consistent with this interpretation, secure cover at the edge is an important variable in the model and an important characteristic of openings that attract elk.

Management Implications for Elk

The 2 models of elk response to clear-cut openings are based on 7 independent variables that assume greater or lesser degrees of importance depending on existing structure of the available environment and the experience of animals in that environment. In general, elk response in habitats with a shrub understory and few natural openings will follow the western Montana model, whereas natural openings and a weak shrub component will lead to a response similar to the eastern Montana model. The manager's selection of an appropriate model for any specific situation depends on some prior knowledge of existing elk habitat and may involve combinations taken out of both models.

Slash Management.—There is little reason to suspect, for example, that elk response to slash is not consistent throughout elk summer ranges. The fact that slash was not selected as an important variable in the eastern Montana model was a function of available data. Eastern Montana forests simply produce less slash, and few of the sampled clear-cuts had more than the 0.5 m of slash required to affect elk use of openings. A similar relationship exists with regard to dead-and-down material in the uncut forest. The smaller stems and shorter crowns of eastern Montana timber apparently produce less of a barrier to elk movement.

Opening Size.—The area of an opening provides only 1 measure of a basic requirement for adequate security in elk habitat. Size of opening, in fact, may be less important than some other considerations—particularly for elk herds that normally spend at least part of the year on ranges with large natural openings. Even in western Montana, the difference between 20 and 40 ha was less significant to elk than 0.2 m additional untreated slash in the opening.

Cover.—Another measure of the secu-

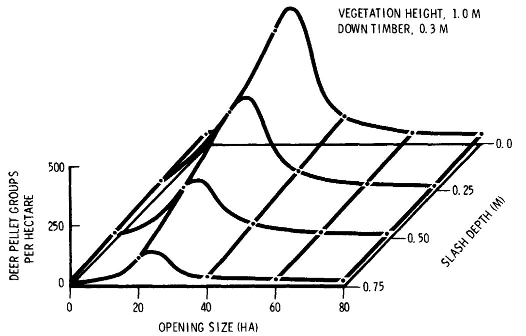

Fig. 5. Submodel for predicting deer pellet-group densities in clear-cuts, western Montana.

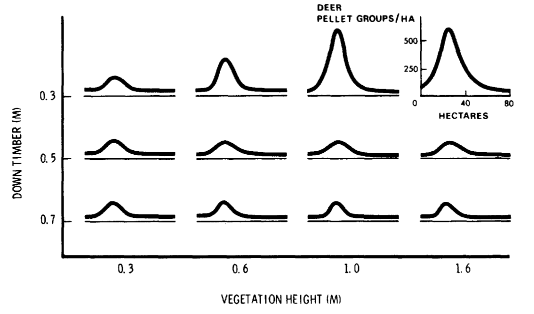

Fig. 6. Submodels for predicting deer pellet-group densities in clear-cuts, western Montana.

rity requirement is provided by elk response to hiding cover at the edge of or inside sampled openings. In forest types with a grass-forb understory and few shrubs, escape cover at the edge of the opening is extremely important. Alternatively, where shrubs contribute to both cover and forage inside the opening, cover at the edge is less important. Long term planning should also recognize that elk use of a grass-forb clear-cut will probably occur earlier, but will not continue for as many years as elk use of a shrub-browse clear-cut.

Road Management.—Finally, the manager has a significant opportunity to affect security in elk habitat through appropriate road closure and traffic control. The opportunity appears to be greater where animals are feeding in openings that lack cover, but several other studies have confirmed a reduction in elk use of most habitats adjacent to forest roads (Burbridge and Neff 1976, Marcum 1976, Perry and Overly 1976, Ward 1976). Elimination of automotive traffic can be expected to increase the use of clear-cuts that are otherwise acceptable to elk.

RESULTS—DEER MODELS

Mule deer are ubiquitous in Montana and white-tailed deer are common in the mountains of western Montana and in river bottoms throughout the state. Because we know of no way to separate these species on the basis of pellets alone, the following presentations and interpretations treat both simultaneously.

Western Montana Deer

The model derived for predicting the density of deer pellet groups in western Montana clear-cuts includes 4 variables: vegetation height inside the opening, slash depth inside the opening, depth of dead-and-down timber in the adjacent forest, and size of the opening. R^2 for the model = 0.71, whereas the linear additive effect of the same 4 variables yields $R^2 = 0.21$.

Graphic interpretation of deer use of clear-cuts in western Montana is supplied by Figs. 5 and 6. Figure 5 represents a submodel for situations in which vegetation height inside the opening is 1.0 m, and dead timber in the adjacent forest averages 0.3 m in depth. Within these constraints, the model represents a surface from which slash depth and area can be used to estimate the number of deer pellet groups/ha inside the clear-cut.

Additional submodels are required to show pellet densities for other combinations of vegetation height and dead-and-down timber depth. Because all submodels have the same conformation, a representative set can be visualized from the curves for deer pellet densities at the back edge (0.0 slash) of each submodel (Fig. 6).

In this model, 2 of the 4 variables that influence deer use of clear-cuts (slash depth and opening size) are controlled by the manager, and a 3rd (vegetation height) can be predicted. From Fig. 5 it can be seen that slash in excess of 0.5 m suppresses deer use of openings by at least 50%. Figure 6 shows that a similar reduction in deer use can be expected when dead-and-down timber in the uncut adjacent forest exceeds a depth of 0.5 m. Forested areas with heavy accumulations of downed material are avoided by deer.

Where dead-and-down timber is not limiting, an optimum opening size is about 24 ha. A reduction in deer use of about ½ can be expected if the opening size is either doubled or halved. Deer use of newly created openings is limited but increases substantially when vegetation height exceeds 0.3 m, and then levels off after vegetation reaches 1.0 m.

Eastern Montana Deer

The model derived for predicting the density of deer pellet groups in eastern Montana clear-cuts includes 4 variables: elevation of the opening, depth of dead-and-down timber in the adjacent forest, vegetation height inside the opening, and cover quality of the uncut adjacent forest. Cover quality is based on the same subjective scale used for the elk model. R^2 for this deer model = 0.32, while the linear additive effect of the same 4 variables yields R^2 = 0.21.

Figure 7 presents a submodel for situations at 2,150 m where dead-and-down timber in the adjacent forest averages 0.5 m. Within these constraints, the model represents a surface from which vegetation height in the opening and cover quality of the adjacent forest can be used to estimate the density of deer pellet groups inside the clear-cut.

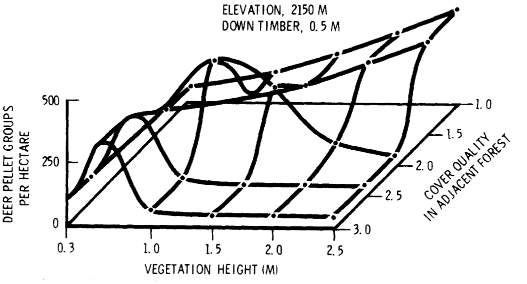

Fig. 7. Submodel for predicting deer pellet-group densities in clear-cuts, eastern Montana.

Additional submodels are required for other combinations of elevation and downed timber depths. However, the eastern Montana deer model has severe limitations, and a single figure is considered adequate for discussion. Of the 4 models presented in this paper, that depicted in Fig. 7 is the least satisfactory. The interactions indicated are unusually complex, and direct application is limited because none of the variables selected is manipulated easily by the manager. In addition, the model is weak in that nearly 70% of the indicated variance remains unexplained.

Nevertheless, the model does provide some basis for speculating about the responses of deer to clear-cuts in eastern Montana forests. For example, the structure of Fig. 7 indicates that deer use of clear-cut openings increases with vegetation height growth in the opening, but that the peak of use is determined by cover quality in the adjacent forest. If cover quality is considered to be an indirect indicator of tree regeneration densities in the clear-cut, the model can be considered indicative of deer response to forage availability.

Where the adjacent forest provides good cover, it also provides an excellent seed source. Seedling densities are high in the clear-cut, and the period of forage availability is short. Conversely, where adjacent cover quality is poor, seedling densities are low and forage is available for a longer period.

Other independent variables in this model indicate that the majority of deer pellets in clear-cuts were found at about 2,150 m elevation and that higher deer populations were found in conjunction with greater dead-and-down timber depths. This latter relationship is the reverse of deer response to downed timber in western Montana and certainly does not satisfy the analytic requirement of agreement with expected trends. We believe that some further examination of the influence of dead-and-down timber is indicated. We have already suggested that the smaller stems and shorter crowns of eastern Montana timber apparently produce less of a barrier to elk movement in overmature forest stands. Apparently, deer movement is not inhibited either, and there also may be some security associated with downed timber where forest stands lack a shrub understory.

As an alternative to this somewhat forced interpretation of a weak model, it seems reasonable to suggest that clear-cuts are of no particular relevance in eastern Montana deer habitat. Our assumption in modeling was that a created opening is either more attractive or less attractive than the unmodified habitat. The weakness of this model implies that other unmeasured characteristics of the environment are far more important to deer in eastern Montana than clear-cuts.

Management Implications for Deer

The 2 models of deer pellet distributions in response to clear-cut openings demonstrate less consistency than the 2 elk models. Nevertheless, both provide information that can assist the manager in predicting consequences of timber harvest in deer habitats.

Slash Management.—Adequate slash disposal, for example, is suggested by the strong negative response of western Montana deer to slash depths over 0.5 m. Such slash depths were rarely encountered in eastern Montana, but it seems certain that inadequate disposal of logging slash will reduce deer use of clear-cuts in any habitat.

Opening Size.—In common with elk, deer responses to opening size appear to be at least partially conditioned by familiarity with large natural openings. In western Montana, where natural openings are few, a definite preference was indicated for clear-cuts of about 24 ha. Eastern Montana deer apparently were not influenced by opening size.

Cover.—In all Montana clear-cuts, deer use of openings increased as cover height in the opening increased. The period of use and timing of peak use were determined by an interaction between cover height and forage production in the opening. Where cover height growth does not inhibit understory forage development, maximum use of openings by deer will occur shortly before cover height reaches 1.0 m.

SUMMARY AND CONCLUSIONS

Distributions of elk and deer pellet groups in and around 87 clear-cuts in Montana forests indicated influences of both ungulate distribution and a number of complex interactions between animals and the forest environment available to them. Four models of elk and deer use of clear-cuts are presented. In general, these models suggest that big game animals enter clear-cut openings because the openings contain either better quality or greater amounts of forage than the surrounding uncut forest. However, the ability or willingness of animals to seek forage in an opening is tempered by a requirement for security. This requirement is expressed in a number of ways, some of which are locally modified by past experiences of animals in the available environment.

Elk apparently have much higher security requirements than deer. Both deer and elk preferred clear-cuts with cover in the opening except where such cover inhibited forage growth. Both preferred openings in which logging slash was not a barrier to easy movement. Both appeared somewhat unwilling to enter large clear-cuts in heavily forested environments, but the size of the openings was less important to animals where large natural openings were present. Elk preferred smaller clear-cut openings than deer, but were more tolerant of large openings. Elk use of clear-cuts, however, was severely depressed by the presence of active roads and inadequate cover at the edge of the opening.

In summary, big game response to clear-cuts and utilization of the openings is a complex function of forage and cover requirements modified by the behavioral patterns of animals in the local environment. Predictions of probable use by both deer and elk can be made for clear-cuts in many forest environments, but the reliability of such predictions depends on adequate information about forage development patterns in the openings and on habitat conditions that assure the forage produced is actually available to big game animals.

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