Elk Habitat Selection and Winter Range Vegetation Management in Northwest Montana

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Abstract

We determined winter and spring habitat selection of a small (~100) resident elk (*Cervus elaphus*) herd from 1988 to 1998 including 3 years before to 6 years after timber harvest and/or prescribed burns. Sixty-nine elk were fitted with radio transmitters to document elk response to these habitat treatments. The study area was located on Firefighter Mountain along the west shore of Hungry Horse Reservoir in northwestern Montana. Treatments included burning 66 ha of shrubs in eight natural openings and removing coniferous overstory on 251 ha in 48 logging units. We detected no difference pre- to post-treatment in elk selection for the treatment area from within their seasonal home range. Habitat treatments did not influence elk habitat selection. However, snow negatively affected their selection for the treatment area, which suggested forest canopy cover was important to elk in this study area. Thus, opening the forest canopy to increase winter forage production seemingly did not benefit elk. Managers should use caution when managing forests to create forage openings on winter ranges with high snowfall.

Key Words: *Cervus elaphus*, elk, habitat management, Montana, snow, winter range.

Introduction

Managers commonly enhance forage production on elk (*Cervus elaphus*) winter range to increase elk productivity, survival, or change winter distribution. The Rocky Mountain Elk Foundation has funded > 2600 habitat enhancement projects in 27 states (Rocky Mountain Elk Foundation 2007). These projects included a variety of treatments, of which some were designed to increase forage production. Managers typically justify this work on the *a priori* assumption that winter forage is a limiting factor and that increasing forage will increase elk survival and population size. However, no studies have demonstrated increased elk production or survival as a result of habitat enhancement designed to increase forage production on forested winter ranges. In fact, past studies have warned that manipulation of cover on forested elk winter ranges may not improve elk habitat and should be designed with great care (Thomas et al. 1979, Lyon et al. 1985).

The effect of snow on elk habitat use in the vicinity of our Firefighter Mountain study area in northwestern Montana is well documented (Jenkins 1985, Singer 1979). Elk preferentially use timbered habitats at snow depths greater than 60 cm (Telfer and Kelsall 1971, Leege and Hickey 1977, Singer 1979, Peck and Peek 1991). Jenkins (1985) found that habitat use by elk was related to overstory density during a severe winter in the North Fork of the Flathead River. Martinka (1976) found elk densities west of the continental divide in Glacier National Park were highest on winter ranges in intermediate seral stages and stressed the importance of habitat structure in areas of deep snow.

The objective of our project was to evaluate a long-term management plan intended to improve winter range and thereby increase carrying capacity by an additional 133 elk (D. Casey and P. R. Malta 1990, unpublished report). Our approach used radio-equipped elk to test an assumption that poor interspersion of cover and forage and a deteriorating forage base (due to fire suppression and conifer density) limit elk population size on Firefighter Mountain in northwestern

Montana. Alternatively, elk populations may not respond numerically but may respond by changing their distribution to increase use of treated habitats. Montana Fish, Wildlife and Parks identified the project area for potential treatment based on preliminary field work conducted during 1987-89 (D. Casey and P. R. Malta 1990, unpublished report).

Study Area

The Firefighter Mountain study area is located on the northeast shore of Hungry Horse Reservoir along the South Fork Flathead River in northwest Montana (Fig. 1). USDA Flathead National Forest manages the land. During our study there were < 0.25 km/km^2 of road open to motorized vehicle use in the study area during the fall elk hunting season. Hunting regulations remained constant during the course of the study. A 6-week archery season allowed harvest of any elk, followed by a 5-week firearms season that allowed harvest of any elk during the first week and any antlered bull during the last 4 weeks.

A nonmigratory elk herd occupied the 19,847-ha study area, including Firefighter Mountain and adjacent range, during 1 December to 14 May from 1988 to 1997 (J. Vore, P. R. Malta and E. Schmidt 1995, unpublished report). Pacific maritime weather patterns prevailed on the study area (Daubenmire 1969). Mean annual precipitation at the Emery Creek Snow Telemetry (SNOTEL) site 2.8 km northeast of the study area (elevation 1327 m) was 106 cm (SE = 7.50 cm) during water years (1 Oct- 30 Sep) 1988-1997 (USDA Natural Resource Conservation Service 1988-1997). SNOTEL sites were automated stations that collected and transmitted the daily snow water equivalent (SWE) from snow pillows, total precipitation (accumulated from 1 Oct each year), and daily air temperatures. Approximately half of annual precipitation fell as snow from October through March although winter rains were common. Snow was commonly > 1 m deep on this elk winter range. Elevation in the mountainous topography ranged from 980 to 2000 m.

A closed-canopy forest dominated the study area; there were relatively few natural openings and scattered clearcuts created by past logging. Clearcuts < 10 years old in the area had scattered trees < 2 m tall, whereas older clearcuts were typically more densely vegetated with shrubs and trees > 2 m tall. Lodgepole pine (*Pinus contorta*) and western larch (Larix occidentalis) were the dominant conifers, while Douglas fir (*Pseudotsuga menziesii*) occupied more xeric south and southwest aspects below 1500 m. Subalpine fir (*Abies lasiocarpa*) was common above 1800 m. Pacific yew (*Taxus brevifolia*), alder (*Alnus* spp.), menziesia (*Menziesia ferruginea*) or globe huckleberry (*Vacinnium globulare*) locally dominated understory shrubs. Beargrass (*Xerophyllum tenax*) and pinegrass (*Calamagrostis rubesens*) were ubiquitous throughout the study area.

Ungulates on the study area included elk, mule and white-tailed deer (*Odocoileus hemionus* and *O. virginianus*), and moose (*Alces alces*). Large carnivores included black and grizzly bear (*Ursus americanus* and *U. arctos*), mountain lion (*Felis concolor*), wolverine (*Gulo gulo*), and coyote (*Canis latrans*). Wolves (*C. lupus*) have been sighted, but no known resident packs have become established during the study period.

Methods

Habitat enhancement on Firefighter Mountain consisted of 56 treatment units totaling 317 ha on the south and west side of the mountain (Fig. 1). Eight units totaling 66 ha ($\bar{x}$ = 8.4, range 1.2 - 14.3) were natural openings where shrubs were slashed and burned to stimulate forage production. The other 48 units totaling 251 h a ($\bar{x}$ = 5.3, range 0.9 - 8.4), were either logged or trees were slashed and then burned to open the canopy and stimulate browse production. Timbered units were designed in which no point in a treatment unit was > 180 m from forest cover that was at least 180 m wide. Hereafter, these 48 units are referred to as logging units.

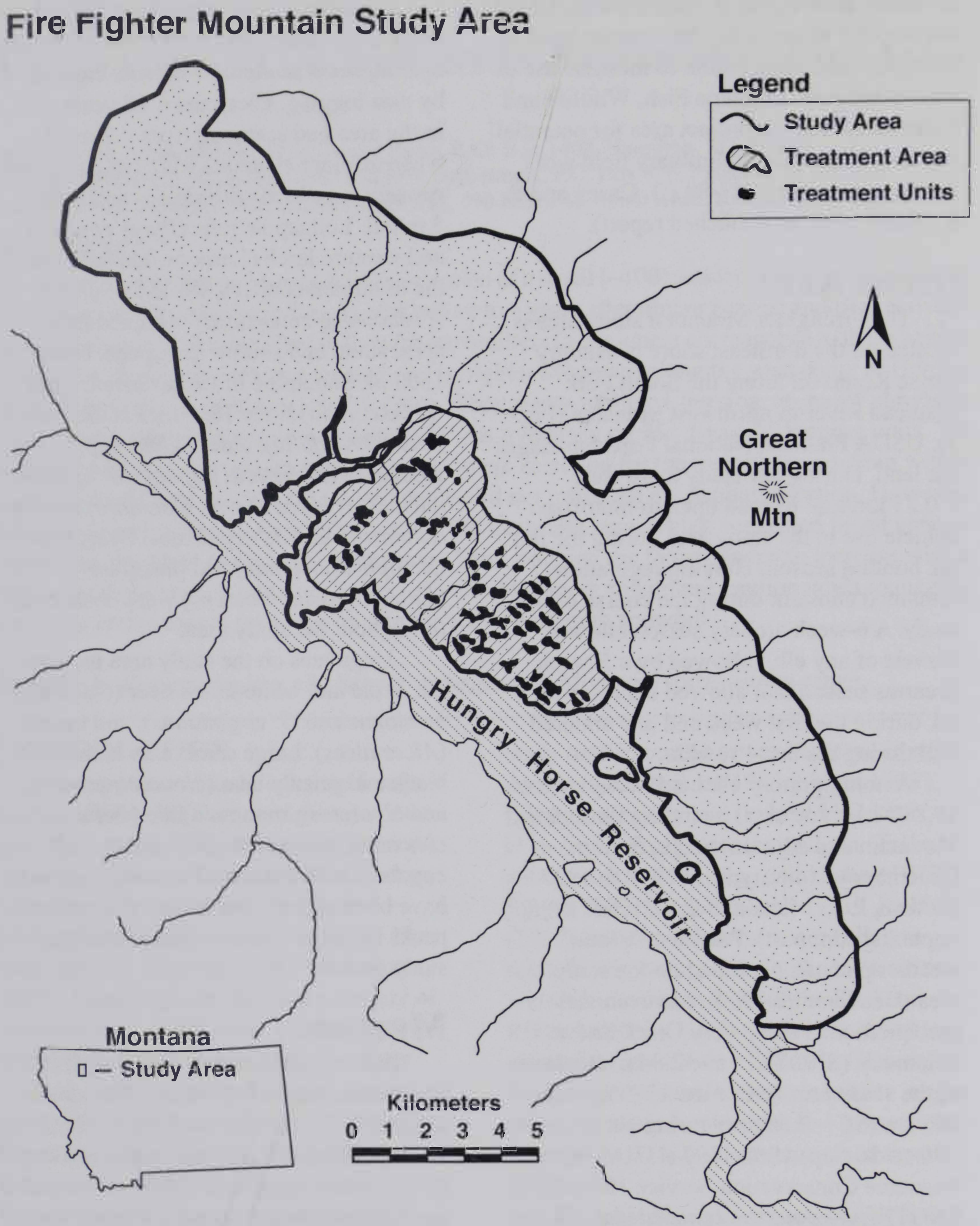

Figure 1. Elk range on the Firefighter Mountain study area in northwest Montana showing location of treatment area and individual treatment units.

With the exception of a single natural opening, closed-canopy forest of dense lodgepole pine with little understory forage production dominated the southern half (46%) of the study area. Pretreatment elk distribution showed little elk use of the southern half other than in the natural opening. Logging units were purposely concentrated (77% of logging units) in the south half to attract more use to this area of relative low forage production.

Habitat treatments began in 1991 and were mostly completed by summer 1995 except for burning of one unit. At the end of the study during winter 1998, treatments on natural openings were 6 years old, and treated logging units ranged from 2 to 6 years old with 75 percent of units ≥ 4 years old.

Project personnel measured vegetation response to treatments in order to evaluate changes in forage production resulting from habitat enhancement efforts using standardized vegetation sampling methods from the USDA Forest Service ECODATA handbook (Hann 1987). We sampled at least 3 sites representative of each primary type of treatment for monitoring, including natural openings, dense seral forest stands, as well as random and control sites with no habitat treatments. We then sampled vegetation on five 0.25-m^2 plots along each of five 20-m transects at 11 permanently marked treatment sites and one control site. We calculated a forage production index by multiplying shrub height by shrub width and dividing the product by the average distance to shrubs along each transect.

Project personnel captured elk from December to mid-March in a corral trap, Clover traps (Thompson et al. 1989) or by net gunning from a helicopter (Helicopter Wildlife Management, Salt Lake City, UT) and fitted them with radio collars (Advanced Telemetry Systems, Inc., Isanti, MN). We located elk from a Cessna 185 aircraft and plotted locations on 7.5-min United States Geographical Survey topographic maps using Universal Transverse Mercator (UTM) coordinates. Mean telemetry error (±1 SE) of 24 locations on 17 radio collars either shed or on dead elk was 196 ± 72 m. We defined an elk group as ≥ 1 animal and it was not uncommon for >1 radio-collared elk to be in a group. In these cases, we used the geographic center of the group rather than coordinates of individuals in the group as our habitat point because the presence of conspecifics can bias an individual's choice of habitat (White and Garrott 1990). We used only locations that were separated by > 4 days (White and Garrott 1990) to insure independence of locations of individuals. This research was conducted using wildlife capture and handling protocols established by Montana Fish, Wildlife and Parks.

We used the Animal Movement extension in the Geographic Information System (GIS) program ArcView 3.1 (Environmental Systems Research Institute, Inc., Redlands, CA) to generate adaptive kernel herd home ranges (Worton 1989) for winter (1 Dec-15 Mar) and spring (16 Mar-14 May). We defined the total and core home ranges by the 100 percent and 50 percent isopleths, respectively, and excluded portions of home range polygons located in Hungry Horse Reservoir.

We defined the "treatment area" for analysis of elk use as that portion of Firefighter Mountain inside a 712-m buffer (mean daily movement of cow elk in spring and early summer [Vore and Schmidt 2001]) around each treatment unit (Fig. 1). The 3480- ha treatment area covered most of the west face of Firefighter Mountain. Few places within the treatment area were > 712 m from a treatment unit because units were designed to maximize interspersion of cover and openings (Fig. 1).

We determined habitat selection at three analysis levels during three time periods: pre-treatment (1988-1991), treatment (1992-1995), and post-treatment (1996-1998). The first level of selection determined selection for the treatment area from within the total home range. Second, because treatment units were concentrated in the southern portion of the treatment area, we evaluated selection between the north and south portions of the treatment area by elk groups located within it. Finally, we examined selection for the treatment units by elk within the treatment area. We buffered each unit by the mean telemetry error and used natural openings, logging units, and the remainder of the treatment area as habitat categories. We further categorized logging units as either cut or uncut during the treatment time period.

The close proximity of units to each other precluded analysis at the individual unit level. Because conversion of closed-canopy forest into forage openings was a primary purpose of the project, we further analyzed selection for logging units by excluding locations in natural openings.

Table 1. Selection by elk for the treatment area on Firefighter Mountain from within an elk herd's 100 percent kernel home range during winter and spring, 1991-1998.

Time Period	Treatment Area	North Herd						South Herd					
		Winter			Spring			Winter			Spring		
		Groups (%)	w[a]	P[b]	Groups (%)	w[a]	P[b]	Groups (%)	w[a]	P[b]	Groups (%)	w[a]	P[b]
Pre-treatment	Inside	28 (26)	1.070	0.685	50 (51)	1.943	0.000	No Data			0 (0)	0.000	0.000
	Outside	81 (74)	0.978		49 (49)	0.669					18 (100)	1.493	
During treatment	Inside	62 (38)	1.575	0.000	59 (44)	1.848	0.000	14 (13)	0.393	0.000	18 (22)	0.665	0.026
	Outside	102 (62)	0.818		74 (56)	0.732		94 (87)	1.299		64 (78)	1.165	
Post-treatment	Inside	19 (27)	1.147	0.506	24 (32)	1.215	0.277	13 (15)	0.453	0.000	15 (23)	0.699	0.075
	Outside	50 (73)	0.955		52 (68)	0.925		74 (85)	1.270		50 (77)	1.148	

[a] Selection Index indicating use less than (<1), greater than (>1), or equal to (=1) habitat availability.
[b] G-test of significance (Manley et al. 1993)

For this analysis we used only those groups that were either in logging units or on the remainder of the treatment area.

We calculated the distance to the nearest treatment unit for elk groups in the treatment area using The Analysis Extension for ArcView (SWEGIS, Göteborg, Sweden). This metric might document a geographic shift in elk distribution that may not be evident by the previous analysis of elk in or out of treatment units. We compared distances pre- vs. post-treatment for natural openings and logging units using Student's *t* test.

We used Programs for Ecological Methodology (Exeter Software, New York, NY) to determine habitat selection using Cock's (1978) selection index found in Krebs (1999:478):

$$w_i = \frac{o_i}{p_i}$$

where: w_i = Selection index for habitat *i*
o_i = Proportion of elk groups in habitat *i*
p_i = Proportion of habitat *i* available

An index of 1 indicates habitat use in proportion to availability whereas > 1 indicates selection for and < 1 selection against a habitat. We used the *G*-test recommended by Manley et al. (1993) to determine differences in habitat selection within a time period and x^2 to compare elk use among time periods.

To evaluate the effect of snow on elk distribution, we used the SWE recorded at the Emery Creek SNOTEL site for the dates on which elk were located (location-date SWE or LDSWE). We regressed the mean LDSWE for each winter against that winter's treatment area selection index. We used the program Statistica (StatSoft Inc., Tulsa, OK) for x^2, Student's t and linear regression analyses and identified significant differences at $P < 0.1$ for all statistical tests.

Results

Vegetation Response

Pretreatment forage production was generally highest in natural openings and lowest among control and treatment sites; random sites were intermediate (Fig. 2). This supported early rationale that forested areas chosen for forage-enhancing treatment were poor forage producers because of their dense forest canopy.

Vegetation response to treatment was greatest in natural openings. The forage production index decreased in response to initial treatment but returned to pre-treatment levels within 4 years. Lengths of unbrowsed twigs increased an average of 17-fold the year after treatment and declined an average of 50 percent/year thereafter. Shrubs in natural openings completely regained their former stature within 5 years post-treatment.

We documented little to no shrub production in the understory of dense forest stands prior to treatment and little shrub response ≤ 6 years following timber harvests. Established shrub communities in natural openings responded quickly to fire treatments. In contrast, forested treatment units did not establish new shrub communities during 2-6 years of monitoring during this study.

Elk Response

We obtained 1199 radio telemetry locations of 69 elk in 1023 groups (543 winter, 480 spring) from 1988 to 1998. Two small (~50 elk) but distinct herds used the treatment area, and we hereafter refer to these as the north herd and the south herd and reported them separately.

Selection for the Treatment Area from within the Herd Home Range

North herd.—The north herd had a 13,287-ha winter home range based on locations of 342 groups. Twenty-four percent of the home range was in the treatment area. Their core winter range was 1046 ha with 53 percent in the treatment area. These elk selected the treatment area over all winters combined (w = 1.328, P = 0.003), but this varied among time periods (Table 1). North herd elk showed no area preference during either the pre-treatment or post-treatment time periods, and the relative amount of use between the two periods was

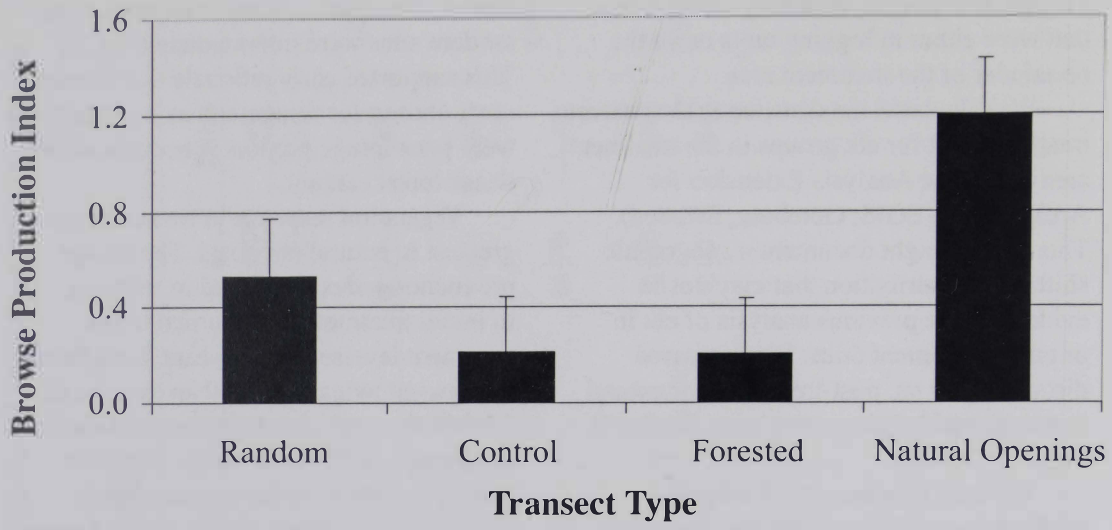

Figure 2. Browse production index ($\bar{x}$ + SE) on random, control and treatment transects on the Firefighter Mountain study area in northwest Montana.

the same (x^2_1 = 0.07, P = 0.785). These elk also selected the treatment area during the years treatment occurred.

Winter selection for the treatment area by the north herd was negatively correlated with the mean LDSWE (F_{reg} = 12.6, P = 0.010) (Fig. 3). When LDSWE was < 9, elk selected the treatment area (w_t = 1.801, P = 0.000, n =155), but this value was exceeded on 48 percent of winter days during our study. When LDSWE was between 9 and 11, elk showed no selection (w_t = 1.292, P = 0.107, n = 96) and used their home range in proportion to availability. When LDSWE was >11, elk selected against the treatment area (w_t = 0.550, P = 0.010, n = 91) and 31

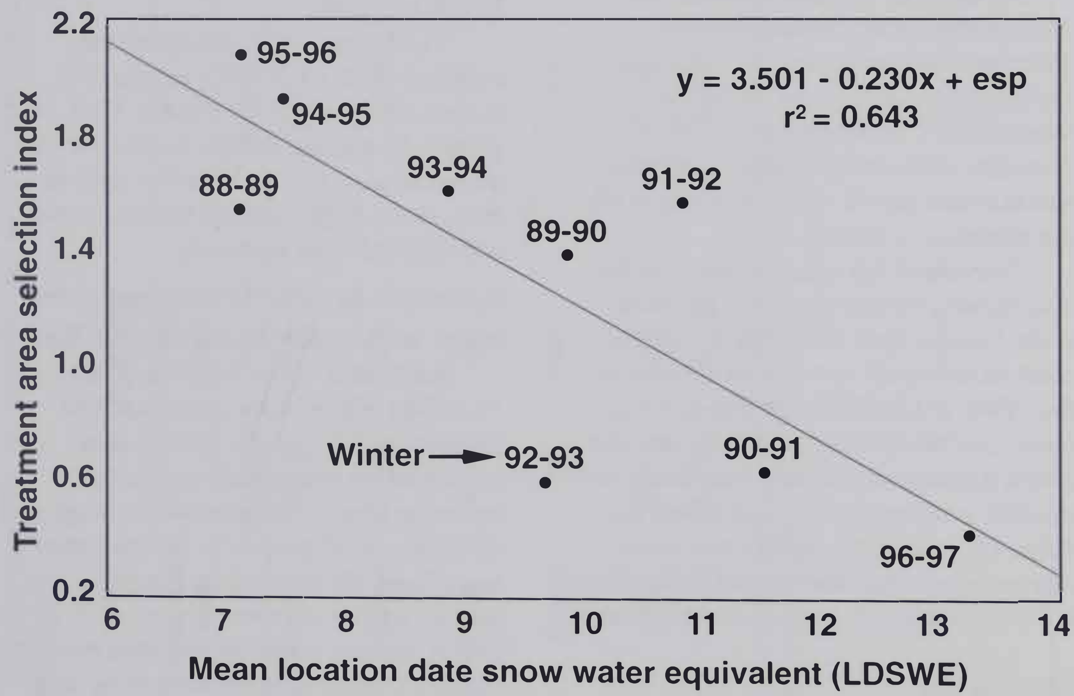

Figure 3. North herd winter selection index by elk for the treatment area as influenced by mean location-date snow water equivalent for winters 1988-89 through 1996-97 on the Firefighter Mountain study area in northwest Montana.

percent of all winter days during our study exceeded this value.

North herd elk responded similarly to snow during both pre-treatment and post-treatment years. Pre-treatment winter 1988-1989 and post-treatment 1995-1996 had the lowest mean LDSWEs ($\bar{x}$ = 7.1 for both), and elk used the treatment area to the same degree each year (x^2_1 = 0.97, P = 0.324). Likewise, we observed highest mean LDSWEs during pre-treatment winter 1990-1991 ($\bar{x}$ = 11.5) and post-treatment winter 1996-1997 ($\bar{x}$ =13.2), and again elk use did not differ between the two (x^2_1 = 0.51, P = 0.477).

In spring the north herd's total and core home ranges were 12,720 and 675 ha, respectively. Twenty-six percent of the total and 64 percent of the core home range was in the treatment area. Over all years elk used the treatment area more in spring than in winter (w^2_1 = 8.87, P = 0.003, Table 1). In the pre-treatment period and during treatment, elk selected the treatment area but showed no preference for it post-treatment. Spring use of the treatment area by elk was less post-treatment than it had been pre-treatment (x^2_1 = 6.31, P = 0.012).

South herd.—We based the south herd's 9608-ha winter home range on locations of 201 groups. Although 33 percent of the total home range was in the treatment area, none of the 926-ha core range included the treatment area. The winter core home range of the south herd was 1.5 km from the treatment area at its nearest point.

The south herd used the treatment area very little in winter. A mean of 14 percent (range = 0-21%) of groups were in the treatment area in winter, and elk selected against it in all winters (Table 1). We had no pre-treatment data for south herd elk because we did not begin trapping these elk until winter 1992. In post-treatment years, 15 percent of south herd groups were in the treatment area. We found no relationship between snow and treatment area selection for the south herd elk (F_{reg} = 0.273, P = 0.623, r^2 = 0.052).

In spring, the total range was 9369 ha with 33 percent in the treatment area. The 900-ha core range was 1.4 km from the treatment area. The south herd elk did not use the treatment area more in spring than in winter (x^2_1 = 2.44, P = 0.119).

Selection for North vs. South Portion of the Treatment Area

North herd.—North herd elk concentrated their use in the northern

Table 2. Selection for the north (2243 ha) vs. south (10598 ha) portion of the treatment area by north herd elk on Firefighter Mountain.

Time Period	Area	Winter Groups (%)	Winter W^a	Winter P^b	Spring Groups (%)	Spring W^a	Spring P^b
Pre-treatment	North	26 (93)	1.720	0.000	46 (92)	1.704	0.000
	South	2 (7)	0.155		4 (8)	0.174	
During treatment	North	34 (85)	1.574	0.000	38 (93)	1.716	0.000
	South	6 (15)	0.326		3 (7)	0.159	
Post-treatment	North	16 (84)	1.560	0.005	20 (83)	1.543	0.003
	South	3 (16)	0.343		4 (17)	0.362	

[a] Selection Index indicating use less than (<1), greater than (>1), or equal to (=1) habitat availability.
[b] *G*-test of significance (Manley et al. 1993)

Table 3. North herd habitat selection by elk within the treatment area for natural openings (13% of area), logging units (35%) or the remainder of the Firefighter Mountain herd range (52%).

Time Period	Area	Winter Groups (%)	Winter w^a	Winter P^b	Spring Groups (%)	Spring w^a	Spring P^b
Pre-treatment	Natural Openings	5 (18)	1.374		22 (44)	3.385	
	Uncut Logging Units	6 (21)	0.612	0.278	7 (14)	0.400	0.000
	Remainder	17 (61)	1.168		21 (42)	0.808	
During Treatment	Natural Openings	10 (16)	1.241		18 (31)	2.347	
	Cut Logging Units[c]	5 (8)	0.504	0.000	5 (8)	0.530	0.002
	Uncut Logging Units	27 (44)	2.292		6 (10)	0.535	
	Remainder	20 (32)	0.620		30 (51)	0.978	
Post-Treatment	Natural Openings	4 (21)	1.619		7 (29)	2.244	
	Cut Logging Units	5 (26)	0.752	0.542	7 (29)	0.833	0.112
	Remainder	10 (53)	1.012		10 (42)	0.801	

[a] Selection Index indicating use less than (<1), greater than (>1), or equal to (=1) habitat
[b] *G*-test of significance (Manley et al. 1993)
[c] Cut Logging Units = 16% of the area, Uncut Logging Units = 19%

portion of the treatment area throughout the study irrespective of the fact that treatment units were concentrated in the southern portion of the treatment area. Ninety percent ($n = 47$) of the north herd groups located in the treatment area were in the north portion during each time period (Table 2). The north herd's winter use of the north and south portions of the treatment area did not differ pre- vs. post-treatment ($x^2_1 = 0.89$, $P = 0.345$). In spring north herd elk selected the north portion (Table 2), and we detected no difference in the amount of pre- vs. post-treatment use ($x^2_1 = 1.26$, $P = 0.261$).

South herd.—South herd elk showed no preference for either portion of the treatment area ($w_{north} = 0.784$, $w_{south} = 1.254$, $P = 0.230$, $n = 27$). During all years combined, 56 percent of winter ($n = 27$) and 73 percent of spring groups ($n = 33$) were located in the south half of the treatment area.

Selection for Treatment Types within the Treatment Area

North herd elk using the treatment area in winter did not select from among natural openings, logging units, or the remainder of the treatment area during either pre- or post-treatment years (Table 3). However, during the years in which units were treated, elk selected for uncut areas scheduled for future treatment (uncut logging units). In spring elk selected natural openings pre-treatment and during treatment, and a small sample ($n = 24$) showed a similar tendency post-treatment (Table 3). Among north herd elk not associated with natural openings, there was no difference in distribution pre- vs. post-treatment during either winter or spring ($x^2_1 = 0.23$, $P = 0.630$ and $x^2_1 = 1.39$, $P = 0.256$ respectively). The small number of south herd groups using the treatment area and the lack of pre-treatment data precluded this analysis for the south herd.

Table 4. Distance of elk to nearest treatment unit pre- vs. post-treatment during winter and spring for north herd elk groups in the Firefighter Mountain treatment area.

Season	Treatment Type	Pre/Post Treatment	Distance (m) $\bar{x} \pm 1SE$	n	t - test P
Winter	Natural Opening	Pre	286 ± 41	17	0.448
		Post	224 ± 66	6	
	Logging Units	Pre	202 ± 75	11	0.485
		Post	266 ± 52	13	
Spring	Natural Opening	Pre	129 ± 33	24	0.229
		Post	210 ± 66	12	
	Logging Units	Pre	232 ± 42	26	0.871
		Post	219 ± 62	12	

Other Potential Responses

Lack of response by elk to habitat treatment was also evident from the distance between north herd elk groups and the nearest unit (Table 4). We found no difference in the distance to the nearest treatment unit in either winter or spring.

An alternative explanation to the lack of elk response might be that vegetation within treatment units did not have adequate time to develop post-treatment. To evaluate this possibility, we looked for a response by elk in only the 10 units that had developed shrub canopies > 15 percent and when SWE was < 11. Results of x^2 analyses showed no significant difference from all other areas in pre-treatment (n = 70 locations) during treatment (n = 34 locations) or post-treatment (n = 43 locations) time periods (P > 0.2).

Discussion

Snow depth greatly influenced elk habitat use in our study area where high snowfall (>1 m) was common. Typical winter ranges for elk in Montana are more open, grass-dominated, and receive and retain less snow compared to our study area. Snow depths at sites where elk had foraged on Firefighter Mountain during the 1997 winter averaged 89 cm and were 2 to18 times that measured on five other Montana and Wyoming winter ranges that received measurable snow (Pils et al. 1999). There was no measurable snow on these other ranges during 20 percent of the sampling periods.

The regression presented in Figure 3 suggested that excessive snow depths during 31 percent of the winter days during our study precluded the north herd from using treatment areas. Use of the treatment area by south herd elk was not influenced by snow because none of their core home range occurred in the treatment area. Elk shifted their distribution in response to changing snow depth, but neither herd responded to utilize habitat modified by the treatments. This suggested that snow depth, as influenced by forest canopy cover, was a primary driver of winter elk distribution and habitat use in this area.

In addition to snow intercept, conifer stands also provide forage. Conifers and associated arboreal lichen are important winter forage for elk in northwest Montana (Jenkins 1985, Jenkins and Wright 1987, Baty 1995). Jenkins (1985) and Baty (1995) considered conifers a winter dietary staple. Gaffney (1941) documented heavily browsed lodgepole pine stands on elk winter ranges in the South Fork of the Flathead River in 1935-1937 prior to forest successional changes resulting from fire suppression. On Firefighter Mountain 33 percent of the elk winter diet included lodgepole pine, Douglas fir, and Pacific yew (J. Vore, P. R. Malta and E. Schmidt 1995, unpublished report). Nutritional quality of this diet was as good or better than that on grass winter ranges in Montana and Wyoming (Pils et al. 1999). Removal of the overstory also lowered availability of arboreal lichen. Stevenson (1979) found that even selective logging reduced lichens by 75 percent.

We documented no increase in use of treatment units in the Firefighter Mountain study area. Habitat use was regulated by deep snow conditions that persisted from late winter into early spring. By the time snow had melted and vegetation was readily available, elk had moved on to spring calving ranges leaving inadequate data to evaluate late spring or early summer use within treatment areas.

Management Implications

In deep snow environments where elk habitat use is influenced by snowfall, treatments intended to increase winter forage production at the expense of forest canopy cover may not be warranted. Thus, managers should explore silvicultural options that increase understory production but maintain snow intercept and forage including availability of coniferous browse and lichen production. These habitat conditions seemingly are key to maintaining higher elk densities through winter in a portion of the northern Rocky Mountains, such as northwest Montana, that typically receives a majority of its annual precipitation in the form of snow during winter.

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