Environmental Management (2010) 46:101–109
DOI 10.1007/s00267-010-9502-6

Road and Rail Side Vegetation Management Implications of Habitat Use by Moose Relative to Brush Cutting Season

Roy V. Rea · Kenneth N. Child · David P. Spata · Douglas MacDonald

Received: 13 July 2009 / Accepted: 28 April 2010 / Published online: 17 May 2010

Abstract Plants cut at different times produce resprouts that vary in their nutritional value relative to when they are cut. To determine how vegetation management in transportation (road and rail) corridors at different times of the year could influence browse quality in the years following cutting, and how this could potentially influence encounters between herbivores and vehicles, we undertook a 3-year study. In 2001, at a wildlife viewing area near Prince George, British Columbia, Canada, we established a control area and treatment areas where shrubs and trees that are used as food by moose (*Alces alces*) were cut at the beginning of June, July, August, September, and October. In the fall, moose were most often observed browsing the resprouts of plants cut in August (years 1 and 2 post-treatment) and September (year 3). Cumulative winter track counts were highest in the uncut control area in the years following cutting. Spring pellet counts revealed that most pellets were deposited in the uncut (years 1 and 2) and August-cut (year 3) areas during winter. With the exception of the first year after cutting, browse removal by moose was highest for plants cut later in the growing season. Overall, our findings suggest that following cutting, plants cut later in the year are selected more often by moose relative to those cut earlier. To reduce browse use of corridor vegetation in areas where concerns for moose-vehicle collisions exist, we recommend that vegetation maintenance activities be conducted in the early summer months of June and July.

Keywords Brush-cutting · Forage · Moose · Plant quality · Selection · Vegetation management

R. V. Rea (✉)
Natural Resources and Environmental Studies Institute, University of Northern British Columbia, Prince George, BC V2N 4Z9, Canada
e-mail: reav@unbc.ca

K. N. Child
Engineering Environmental Services, British Columbia Hydro & Power Authority, Prince George, BC V2N 2K4, Canada

D. P. Spata
Corporate Environmental Services, British Columbia Rail Ltd., Prince George, BC V2N 2K8, Canada

D. MacDonald
Public Affairs and Road Safety, Insurance Corporation of British Columbia, Prince George, BC V2L 5B8, Canada

Introduction

Feeding is the predominant activity of moose (*Alces alces*) and other ungulates in transportation corridors (Peek and Bellis 1969; Puglisi and others 1974; Groot Bruinderink and Hazebroek 1996). Since plant quality and attractiveness in transportation corridors are known to influence the amount of time moose spend near roads and rails (Jaren and others 1991), eliminating plants or decreasing plant quality have been suggested as countermeasures that could be used to mitigate ungulate-related vehicle collisions (Jaren and others 1991; Lavsund and Sandegren 1991; Gundersen and others 1998).

Plant–based mitigation strategies previously employed include removal of the forage base, spraying chemical deterrents, planting non-browse species or installing alternative food sources and feeding stations (Jaren and others 1991; Lavsund and Sandegren 1991; Gundersen and others 1998). Unfortunately, these strategies tend to be too expensive to implement across the landscape (Jaren and others 1991; Sielecki 2000), are not environmentally appropriate, or permanently destroy habitat for other wildlife (Oetting and Cassel 1970).

Roadside brush-cutting is practiced regularly in many parts of the world to increase sight lines for motorists and reduce vegetation growth under adjacent utility lines. Because the nutritive quality of plants can be altered as a result of tissue removal at different times of the year (Gutteridge 1997; Alpe and others 1999; Rea and Gillingham 2001), one potential method of reducing the attractiveness of road and rail side plants to herbivores could be to cut at more strategic times (Rea 2003). Elucidating a cutting time that stimulates plants to produce lower quality and less attractive resprouts could allow for the employment of conventional cutting methods that are more cost-effective and at the same time discourage corridor use by browsers.

Moose and several other large herbivores prefer browse shoots that are large, low in tannin, cellulose and lignin, and high in digestible energy and digestible protein (Bryant and Kuropat 1980; Danell and others 1985; Regelin and others 1987; Risenhoover 1987). Although such attributes are known to change in the resprouts of plants following brush-cutting at different times of the year (Hardesty and others 1988; Rea and Gillingham 2001), how moose or other herbivores perceive and alter foraging strategies relative to such changes (i.e., their consumption of shoots from plants cut at different times) is unclear.

As part of a 3-year study in which we measured use of resprouts from brush-cut plants, we recorded variations in the way moose utilized habitat and browsed woody shrubs and trees in areas that were cut at different times of the year in a wildlife viewing area. Our objectives were to: (1) determine the influence of brush-cutting time on plant quality and attractiveness to moose and (2) recommend cutting times based on our results outside of the transportation corridor for vegetation maintenance activities within transportation corridors that resulted in the production of browse that was least attractive to moose.

Study Area

Research was conducted in the Tabor Mountain Wildlife Viewing Area (53° 54’ 35.98”N, 122° 19’ 39.36”W) in the Grove Burn, approximately 30 km east of Prince George, British Columbia, Canada. The site is located in the sub-boreal spruce forest ecotype (Meidinger and Pojar 1991). The climate is generally wet and cool, with precipitation evenly distributed throughout the year. Mean annual temperature at Prince George is 4.0°C, and ranges from a monthly mean daily average of -9.6°C in January, to a monthly mean daily average of 15.5°C in July. The mean annual precipitation is 600.8 mm, with 216 cm of it falling as snow (Environment Canada 2010). The landscape is dominated by coniferous forests of hybrid white spruce (*Picea engelmannii* x *glauca*) and subalpine fir (*Abies lasiocarpa)*. Lodgepole pine (*Pinus contorta* var. *latifolia*) and trembling aspen (*Populus tremuloides*) pioneer secondary successional sites (Meidinger and Pojar 1991), as do several species of upland willows (*Salix* spp.) (Porter 1990).

In 1961, a wildfire burned the area in which we subsequently located our research site. In the years following the fire, the site was pioneered by early seral vegetation (e.g., willows and alder *Alnus* spp.) and served as prime winter range for moose and deer for several decades.

To take advantage of the wildlife viewing opportunities in the area, a local wildlife club (Spruce City Wildlife Association, Prince George, BC) collaborated with the BC Ministry of Environment, Hudta Lake Correctional Institute, and the Habitat Conservation Trust Fund to create a wildlife viewing area in the Grove Burn in 1979. The wildlife association built a wildlife-viewing platform approximately 4 m above the ground, approximately 250 m to the north of the Yellowhead Highway 16 East to Jasper, AB. With the platform as the focal point, 6 linear strips approximately 1-2 ha in size were cut away from the platform using a Hydroaxe. The strips ranged in orientation away from the platform from 80°NE to 330°NW (Fig. 1).

The terrain at the site is predominantly flat, but slopes down and away from the viewing platform in all directions at approximately a 5% grade. The site has served as a

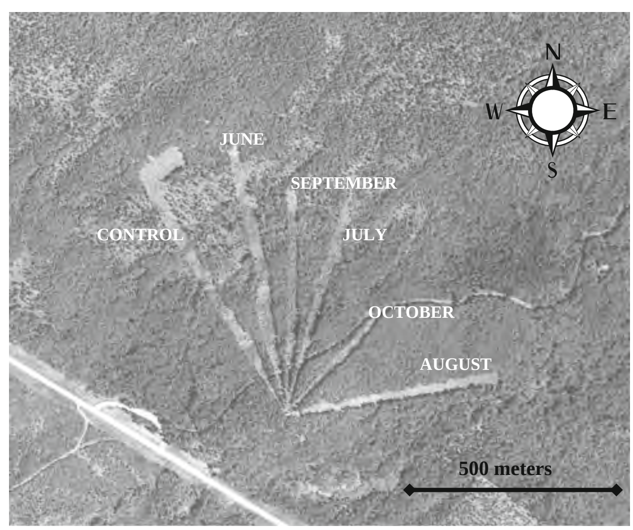

Fig. 1 The Tabor Mountain Wildlife Viewing Area established by clear cutting strips in 1979, provided a unique study area for the project. Strips were randomized and all second growth vegetation was cut at different times of the year in 2001 (indicated by month cut). Moose browsing in any of the strips radiating away from the platform could be monitored simultaneously by one observer

wildlife viewing area since the area was developed for that purpose in 1979. In 1990, larger maturing shrubs and trees that began pioneering the site in 1979 were again cut back on each strip with chainsaws by Spruce City Wildlife Association members, while smaller plants were left uncut. This cutting was performed to increase sight lines and promote browse production to enhance moose viewing opportunities. We could detect no visible difference in the composition or seral stage of the vegetation growing in these strips when we selected the site for the current experiment.

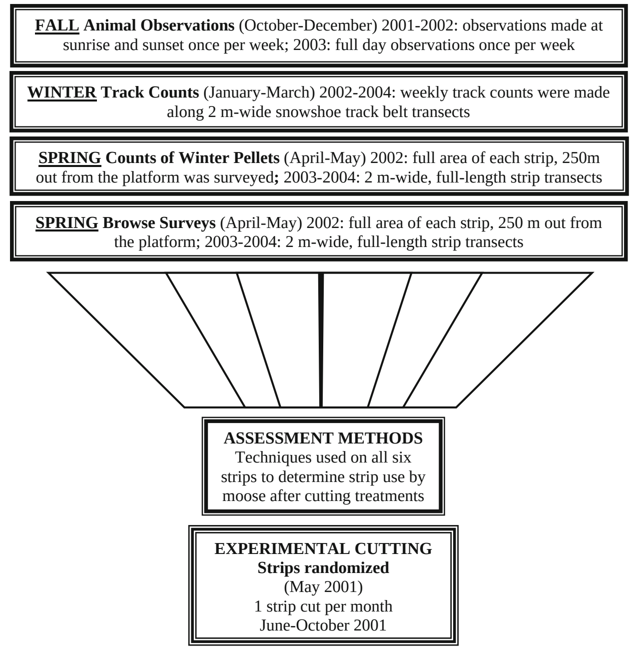

Fig. 2 A diagrammatic representation of the seasonal methods used during our study to collect data from the wildlife viewing area

Methods

In May 2001, we randomized these managed strips and assigned each one to a cutting date. Strips were not selected as a means or intended to imitate road or rail corridors. Although the viewing area was close enough to the highway ($\sim$250 m) for highway noises to be heard, road effects such as car exhaust, vehicle movements, headlights and corridor infrastructure were all absent. This removed important factors present within transportation corridors, but allowed us to specifically test the effects of brush cutting on browsing and habitat use without the confounding influences of traffic and corridor maintenance activities. We also selected the viewing area because it provided a space for us to clearly separate treatment areas using mature forest buffers (see Fig. 1) growing between the strips and provided us with the ability to clearly view moose browsing in treatment areas following timed cuttings.

Strips were brush-cut at the beginning of June, July, August, September, and October of 2001. One strip remained uncut to serve as a control. All plants were cut at approximately 10 cm above the ground. Within these strips, we monitored plant response to cutting time (these findings can be found in a companion paper—Rea and others 2007) and then assessed utilization of plant resprouts and movement patterns of moose. We assessed overall utilization by using direct observations, track counts, pellet counts and browse utilization surveys during each year of the study (Fig. 2).

Fall and Winter Surveys

Moose Observations

To determine which resprouts from which cutting treatments were being used preferentially by moose, we monitored moose browsing activity from the observation tower. We recorded observations between mid-October and mid-December of 2001, 2002 and 2003.

In the autumn of 2001 and 2002, an observer was stationed at the viewing platform once per week for approximately 2 hours just prior to and 3 hours following sunrise and for approximately 3 hours prior to and 2 hours just following sunset. In an effort to ascertain whether or not we were missing important feeding activities over the course of the day by restricting our observations to morning and evening hours, observations were made once per week all day from just 1 hour prior to sunrise to just 1 hour after sunset in the autumn of 2003.

Following strict training procedures in which all observers were trained on site by the principal investigator to ensure consistency in our counting technique, moose behaviour was observed and recorded by slowly and methodically scanning each strip with the naked eye and binoculars at 2 to 3 minute intervals. If we observed an animal in a strip, we used a 15-60 x 60 mm zoom spotting scope and recorded as much as we could about the animal and its behaviour while simultaneously scanning the other strips for any other animal activity. For the purpose of this study, we specifically recorded the amount of time each moose spent browsing within each strip.

Track Counts

We performed weekly track counts in all 6 strips from January through March 2002, 2003, and 2004 to determine moose activity in each strip. We laid out transects using snowshoes down the length of each strip and we counted the number of moose tracks bisecting these transects on a weekly basis in each strip. To reduce the occurrence of accidentally counting a set of moose tracks more than once from moose that were using the snowshoe trail, we considered tracks distinct if the track set deviated more than 1 m beyond the transect. Once tracks were counted, we marked the set of tracks where they left the snowshoe trail with a snowshoe imprint to reduce the chances of double counting.

Spring Surveys

Pellet Counts

We counted all moose pellets after snow melt that fell within areas assessed for browse use. Because more than half of the pellets we found were scattered down trails and throughout the strips (apparently due to moose walking while defecating) and were not contained in "groups" per se, we elected to report total pellet numbers. We included areas in each of the strips within 250 m of the observation tower in the spring of 2002 and then along 2-m wide belt transects that ran diagonally down the length of each strip in the springs of 2003 and 2004 (see Rea and others 2007). We included only newly deposited pellets, not the previous year's (which we smashed underfoot during survey periods), in these counts and then normalized the counts to account for variation in differences within individual strip dimensions. New pellets were those that would have been deposited by moose and remained frozen during the cold season between the fall (September/October) and when we performed spring surveys (April/May).

Browse Use

We assessed percentage of browse used for each plant in the survey areas described above by counting the total number of shoots browsed on each plant and dividing that by the entire number of shoots on each plant. In rare cases (usually in the uncut control strip), we calculated browse use on large, multi-stemmed plants by performing the same calculation on one third or one half of the plant and then multiplying that number by 3 or 2, respectively. We report predominantly on differences in browse use between the 4 most abundant browse species at the site (willow, alder, birch and twinberry), but also report on the combined use of all browse species within each treatment.

Statistical Analyses

We tested differences in percent browsing (number of shoots removed) between plants in various treatment areas using analysis of variance (ANOVA; Sokal and Rohlf 1995). We tested homogeneity of variances using a Levene's test (Milliken and Johnson 1984). We used a Kolmogorov-Smirnov test to test assumptions of normality (Zar 1984). When sample sizes were approximately equal, we used a Tukey's HSD test for post hoc comparisons; otherwise we used a Spjotvoll/Stoline for unequal sample sizes test for post hocs (Zar 1984). Additionally, we report basic statistics for differences between moose observations, track counts and pellet counts between treatment strips (areas cut at different times of the year). Track and pellet count data were normalized to account for variation in strip lengths. We did not calculate percent differences in our results from controls because leaving plants uncut is one of several management options for which we wanted to report treatment effects.

Results

Moose Observations

Most moose were observed using browse in the August-cut strip during the autumns of 2001 and 2002 (Fig. 3). In 2003, moose were seen in the morning and evening hours as in 2001 and 2002, (and only once in mid-day) and most often in the September-cut strip. Moose were never observed in the October-cut strip and only one moose was observed in the July-cut strip (autumn 2001; Fig. 3).

Track Counts

The uncut control strip had the highest cumulative count and 3-year average of moose tracks during each year of the study (Table 1). The October-cut strip had the lowest number of tracks each year, with July having the second to

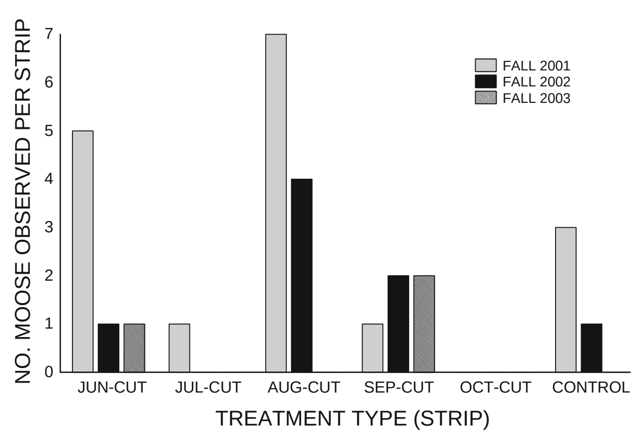

Fig. 3 Total number of moose observed browsing treated plants between early October and mid-December 2001, 2002 and 2003 in strips (treatment areas) that had been brush-cut at different times during 2001

Table 1 Normalized track counts (corrected to the number of track sets counted on a weekly basis and totaled each winter then averaged across 250 m sections of transect—the length of the October strip). Counts were taken from transects that ran diagonally down the entire length of each treatment strip. Counts were made between January and March of each year of the study

Treatment strip	Track counts				
	2002	2003	2004	Totals	3 Yr normalized Ave ± SD
June	18	21	16	55	18.3 ± 2.5
July	14	14	9	37	12.3 ± 2.9
August	19	24	8	52	17 ± 8.2
September	15	22	16	44	17.7 ± 3.8
October	6	8	9	23	7.7 ± 1.5
Control	25	28	18	71	23.7 ± 5.1

lowest numbers of tracks and June, August and September showing moderate levels of activity (Table 1).

Pellet Counts

Of 101 groupings of pellets that we found along our transects, we determined that moose deposited an average of 99.97 ± 25.82 pellets per group. Because of the large variation in pellets per group and the fact that most of the pellets were loosely grouped, or not grouped at all and often merged between groups, we decided to compare total pellets, rather than groups, between treatments. We found that along the width of our sampling areas, most moose pellets were deposited in 2002 and 2003 in the control strip – the strip with the highest 3 year average for pellet deposition (Fig. 4). In 2004, the August-cut strip contained the highest density of moose pellets. With the exception of 2002, the July-cut strip consistently contained the least number of moose pellets (and had the lowest 3 year average) and in 2002 showed the second lowest number of moose pellets following the September-cut strip (Fig. 4).

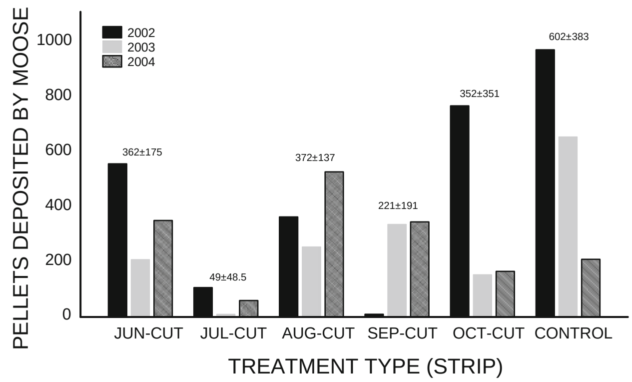

Fig. 4 Number of new over wintering pellets deposited by moose and counted in surveyed areas of each strip during each spring (2002–2004) of the study. Note: Numbers above bars indicate the mean ± 1SD pellets collected in each treatment strips over the 3 year period. In 2002, the areas surveyed included the entire width of each strip for the first 250 m from the viewing platform. In 2003 and 2004, areas surveyed were 2-m wide belt transects that ran the diagonal length of each transect. The 2003 and 2004, total pellet numbers have been normalized to account for differences in strip dimensions (see Methods)

Browse Use Year 1

In the first spring after brush-cutting, willows cut in June and July had been browsed more than those cut in August and uncut controls (Table 2, Year 1). No shoots were produced or available for browse use in the first winter after cutting for plants cut in September or October 2001. There was no difference in browsing on June- and July-cut or August-cut and uncut control willows (Table 2). Twinberry (*Lonicera involucrata*) plants were browsed significantly more in the uncut control strip than in any of the brush-cut strips. August-cut alders were browsed significantly more than July-cut and control alders which were browsed less than those cut in June. Control birches were browsed more than July and August-cut birches (Table 2). Analysis of the average percentage of shoots removed from all browse species (All Brush) present on the site indicates that plants in the control strip were used less than those that had been cut – which all had similar average levels of removal (Table 2).

Browse Use Year 2

In the second year after brush-cutting, October-cut willows were browsed more than June-cut and control willows. June-cut willows were browsed less than October- and September-cut willows (Table 2, Year 2). Twinberry controls were browsed less than June-, July- and September-cut plants, while June-cut twinberry was browsed more than control and October-cut plants (Table 2). September-cut alders were browsed more than control alders (Table 2, Year 2) and control birches were browsed more than birches cut in June (Table 2). In year 2, average brush removals were lowest for plants in the June- and July-cut strips, but similar for all other treatment strips and were highest for the fall-cut strips.

Browse Use Year 3

Three years after cutting, willows cut in October had the highest and June-cut willows had the lowest levels of browsing (Table 2, Year 3) October-cut alders were browsed more than control and August-cut alders which were browsed less than all other treatments (Table 2). Control birches were browsed more than all but October-

Table 2 Mean (±1SE) percentage of plant shoots browsed by herbivores in the first (2001–2002), second (2002–2003) and third (2003–2004) year after cutting and measured in spring after cutting, from different species cut at different times during 2001

Year	Species	Cutting time										Control		*F*	*P*
		June		July		August		September		October					
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
1	Willow	^{271}71.2^{ab}	1.9	^{174}69.2 ^{cd}	2.4	^{615}58.8^{ac}	1.3	–	–	–	–	^{134}55.4^{bd}	2.7	15.09	<0.001
	Twinberry	^{110}27.5^{a}	2.3	^{70}22.3^{b}	2.9	^{21}24.6^{c}	5.3	–	–	–	–	^{156}47.5^{abc}	2.0	24.63	<0.001
	Alder	^{41}15.6^{a}	2.4	^{14}9.6^{b}	4.0	^{14}29.4^{bc}	4.0	–	–	–	–	^{155}3.8^{ac}	1.2	18.47	<0.001
	Birch	^{13}43.0	8.3	^{13}29.7^{a}	8.3	^{51}28.4^{b}	4.2	–	–	–	–	^{13}64.5^{ab}	8.3	5.49	0.001
	All Brush	^{443}53.7^{a}	1.6	^{279}52.2^{b}	2.0	^{716}54.3^{c}	1.3	–	–	–	–	^{494}35.5^{abc}	1.5	22.22	<0.001
2	Willow	^{479}26.0^{bc}	1.4	^{350}30.5	1.7	^{442}31.6	1.5	^{424}32.7^{c}	1.5	^{428}35.6^{ab}	1.5	^{443}29.5^{a}	1.5	4.74	<0.001
	Twinberry	^{326}3.8^{ad}	0.4	^{351}2.6^{b}	0.4	^{289}2.2	0.5	^{325}2.5^{c}	0.4	^{463}1.6^{d}	0.4	^{336}0.5^{abc}	0.4	6.95	<0.001
	Alder	^{63}5.6	2.0	^{78}6.1	1.9	^{59}6.4	2.1	^{84}13.3^{a}	1.8	^{57}9.4	2.2	^{83}1.7^{a}	1.7	4.61	<0.001
	Birch	^{9}38.2^{a}	11.6	^{12}63.1	10.0	^{37}62.1	5.7	^{11}71.7	4.8	^{24}69.8	7.1	^{54}82.2^{a}	4.7	3.31	0.007
	All Brush	^{921}16.3^{ad}	1.0	^{837}16.1^{bc}	1.0	^{945}20.5^{ab}	0.8	^{1112}17.6^{e}	0.9	^{888}21.5^{cde}	1.9	^{1020}19.4	0.9	5.36	<0.001
3	Willow	^{434}14.3	1.4	^{412}26.2^{bde}	1.4	^{395}28.9^{ce}	1.5	^{424}20.8^{ad}	1.4	^{421}39.1	1.4	^{393}25.5^{abc}	1.5	34.98	<0.001
	Twinberry	^{333}0.7	0.2	^{320}0.9	0.2	^{328}0.8	0.2	^{325}0.6	0.2	^{318}1.2	0.2	^{331}0.5	0.2	1.00	0.416
	Alder	^{72}9.6^{acdef}	2.3	^{76}14.6^{dgi}	2.2	^{54}5.1^{bf}	2.7	^{85}16.6^{cgh}	2.1	^{102}17.8^{ehi}	1.9	^{83}4.4^{ab}	2.1	7.08	<0.001
	Birch	^{21}17.9^{bcd}	5.5	^{9}25.1^{cegh}	8.4	^{121}6.5^{dh}	2.3	^{28}23.4^{bef}	4.8	^{34}38.1^{afg}	4.3	^{64}49.9^{a}	3.2	27.35	<0.001
	All Brush	^{932}9.1	0.8	^{856}15.1^{ab}	0.8	^{1160}14.5^{acd}	0.7	^{967}13.3^{bce}	0.8	^{964}21.9	0.9	^{1014}16.1^{ed}	0.8	25.05	<0.001

All Brush refers to combined mean browse removals for all brush species assessed in each strip. Superscripted prefixes indicate sample sizes. Means sharing a common superscripted suffix across a species/group within a year for years 1 and 2 *are* the only treatments significantly different from one another. Means sharing a common superscripted suffix within year 3 across a species/group are *not* significantly different from one another. Tukey's HSD or a Spjotvoll/Stoline for unequal sample sizes tests were used for post hocs. "–" indicates insufficient regrowth for sampling in year 1

SE standard error of the estimate

cut birches and August-cut birches were browsed less than all other treatment categories besides those cut in June and July. (Table 2) Average brush removals in year 3 were highest for the October-cut and lowest for the June-cut plants.

Discussion

Our findings indicate that moose in the Grove Burn used hydro-axed strips that were cut with brush saws at different times during the summer to different intensities in the years after cutting. How much the variation in browsing between strips was related to the effects of brush-cutting treatments or other factors is clear in some respects, but less apparent in others.

In the first 2 years after brush-cutting, moose track and pellet density data show similar patterns of animal activity in treatment strips—both counts were highest in the uncut control strip relative to any of the brush-cut strips. This suggests that, at least after snowfall, moose moved into the control strip and spent most of their time in that area where shoots were available above snow (Schwab and Pitt 1987; Jenkins and others 1990) and did so independent of whether such shoots were more or less attractive or nutritious than those covered by snow in brush-cut strips. In year 3, pellet data show that moose moved into brush-cut strips, likely in response to shoots being longer and more available above winter snows.

Although movement to the control strip was the predominant shift in habitat use in winter, such patterns were not evident in the fall when moose observations were recorded. In fall, more moose were observed using the August-cut strip (at the opposite end of the viewing area relative to the control strip) in 2001 and 2002 and used browse in the September-cut strip predominantly during 2003. In fact, only 4 moose were ever observed using the control strip during the study. Despite these observations, moose may have been using the control or other strips more in the autumn despite the fact that we were unable to observe such use. It was apparent that most moose visitations to the viewing area were under the cover of darkness; most of our observations of moose were recorded just prior to sunrise or just after sunset when moose are known to be most active (Klassen and Rea 2008). Here, the use of infrared monitoring equipment would have helped us to delineate better which strips were being more heavily used, but the type of equipment required to see down the entire length of each strip was too costly for us to acquire.

Because one of our main objectives was to directly observe moose utilization of shoots arising from plants cut at different times, we selected to use the wildlife viewing area (described in the methods section) for our experiment. This made determining which treatment areas that moose were using unequivocal, but did not allow us to use the more technically sound approach of a randomized block design for our cutting and plant response trials (an approach less amenable to unambiguously observing differential selection of treated shoots by moose). Nevertheless, our findings suggest that plant response to cutting followed an intuitive and predictable outcome—namely that plants cut earlier in the growing season produced longer shoots and more biomass than those cut later (Rea and others 2007). Such findings agree with those of others (Kays and Canham 1991) and suggest that plant responses in our trials were based largely on cutting time (the effect we were testing), albeit other potential differences (e.g., edaphic, solar insolation) between strips within the site may have still imposed confounding and unknown influences on plant response.

Although moose viewing was an important part of our study, the most convincing evidence for moose using various strips is pellet deposition and browse use. Pellet deposition has been used by others as an index of habitat use in some areas (Bozzo and others 1992; Härkönen and Heikkilä 1999). Both pellet deposition and browse use allowed us to track evidence of use during those hours that we were not on site to view animals.

Total pellet deposition over the duration of the study was clearly lowest in the July- and September-cut strips. Track data show a very similar trend to pellet data (albeit pellets were also likely deposited in the fall and early spring before and after track counts were made) suggesting reduced use in July- and October-cut strips by moose. Observational data do indicate that fewer animals visited the October-cut strip, but this may have been an artefact of strip length. Of all strips, October-cut was the shortest ($\sim$250 m), at about half the length of the other strips. This made the occurrence of a moose being on the shorter strip less likely. Since most moose observed in the viewing area were generally observed at more than 250 m from the viewing tower, moose uncomfortable with using habitat closer than 250 m from the observer would not likely have used the October-cut strip while the observer was present. Given that pellet deposition and other such surveys overall may be poor indicators of habitat/browse quality unless patch size and distribution at multiple scales are carefully considered (Van Horne 1983), we used direct browse use as another index of plant attractiveness after cutting.

Tracks and pellets at the site suggested that in addition to moose, strips were visited occasionally by deer and hare, but that moose were the predominant visitors to the site. Furthermore, bite marks (type of bite and bite diameter) suggested that the majority of bites on individual plant shoots were from moose. This does not preclude the fact that each bite mark observed may have been taken by moose on shoots that had been previously browsed by moose or other animals and we, therefore, acknowledge the potential error inherent in spring browse surveys.

Except in the first post-cutting year, twinberry and alder plants appeared to be seldom browsed and were likely of little importance for moose when other browses such as willows and birch were available. Altogether dismissing such data, however, would be negligent given that the resprouts from newly cut twinberry and alder formed a large portion of plant shoots at our site consumed by moose in the first post-cutting year relative to how much those plants were used in the second and third year after brush-cutting. That such differences in consumption existed between the first and subsequent years following cutting suggests a uniqueness of quality in first year resprouts relative to older shoots. A general reduction in the percentage of biomass removed by moose with year-since-cutting may also be partially explained by increases in plant biomass with time-since-cutting (Rea and others 2007), if moose removed relatively constant amounts of shoot biomass from each plant browsed. Assessing plant biomass removal from the control site (those plants not compensating for cutting) in the years after brush-cutting suggests that moose drawn to resprouts in cut strips also browsed twice as much in the year after cutting as in the second and third post-cutting years.

With the exception of the first post-cutting year when only the shoots of June- and July-cut plants were available as browse above snow, the shoots of willows (which tend to form an important component of browse plant biomass for moose; Renecker and Schwartz 1998) from plants cut in October were browsed more than those cut in June; July were browsed least. When differences were significant, browse use of birch appeared to follow similar patterns.

Use fluctuated between species and years after cutting, and availability of resprouts with year-since-cutting appeared to influence use of the control strip. Although there was some variation in species composition (e.g., willows ranged from between 12-24% of available individuals in strips), use varied from year to year regardless of species mix. Variation in plant height, architecture, shoot length, biomass, diameters, chemical composition as well as inter- and intra-specific plant juxtapositions and clumping (most of which we did not quantify in this study) in addition to species mixing will, along with other factors, influence foraging by moose (Renecker and Schwartz

1998). Acknowledging our inability to account for each factor and recognizing differences in species preferences by moose, but recognizing from our findings that such preferences may change with time-since-cutting, we also calculated and report an average percent removal of shoots from all species combined (All Brush). Some loss of details in species-specific selection occurs by averaging percent removals, but evaluating broad patterns of percent use also provides an intuitive and generalized index of browse use along road and rail sides where species mixing and plant preferences will vary across the landscape.

Evaluating the overall percent usage of browse (All Brush) indicates the selection of previously cut brush over uncut controls in the first year after cutting and a reduction of use in uncut plants and plants cut in the early, relative to later parts (i.e., August and October) of the growing season in year 2. In year 3, moose appeared to focus their foraging efforts on the shoots of plants cut late in fall and less on those from plants cut early in the growing season.

Reduced consumption of shoots from plants cut earlier rather than later appears logical considering that plants damaged earlier in the year tend to suffer a loss of nutrient input back to roots which consequently have less available resources to allocate to shoot growth in subsequent years (Bryant and others 1991). Additionally, plants damaged earlier in the year produce shoots in the years after the first post-cutting growing season that are smaller, which are less preferred by moose (Penner 1978; Machida 1979; Danell and others 1985; Risenhoover 1987; Shipley and others 1994) and which contain anti-herbivore chemicals that are not found in plants damaged later (i.e., fall and winter) in the year (Bryant and others 1991).

Management Implications

Our findings suggest that important browse species such as willow and birch are used more by moose when cut later in fall than when cut in June and July and that differences in animal use and movements between areas brush-cut at different times of the year could be important from a vegetation management point of view. Our study only provides implications of cutting time within the transportation corridor and would need to be replicated on road and rail sides to test the application of our results in areas where traffic and maintenance activities (such as road deicing) may moderate animal response to plant cutting season. Nevertheless, it would be prudent for corridor managers to consider the influence that cutting season appears to have on moose and other herbivores that may be attracted to vegetation cut at one time of the year versus the other and the implications these interactions may have on the probability of road and rail traffic encountering animals.

These recommendations are not intended for all rights-of-way or even for all stretches of a transportation corridor where healthy populations of herbivores such as moose exist. Obviously, not all road and rail-side areas foster the growth of browse species sought out by herbivores and only some areas of corridor contain the combination of site attributes that make road and rail side browsing attractive. In areas where herbivores are known to use corridor vegetation, however, particularly in collision hotspots, cutting in early summer is recommended. Since the effects of cutting time do not appear to last much longer than 3 years (Rea 1999), cutting in these areas should be undertaken at 3 to 4 year intervals. Where brush-cutting intervals can, however, be performed on a more regular basis (i.e., once per year) recommendations for cutting in early summer should be closely evaluated against fall cutting which removes winter shoot availability altogether.

A reduction in browse quality and or availability through the use of more deliberate brush management planning will not reduce all collisions. However, the integration of these findings into road and rail side vegetation management planning in areas frequently used by herbivores can allow managers to take more proactive measures towards mitigating collisions in a relatively inexpensive and familiar way—simply altering the timing of vegetation management should in no way over complicate the planning process. Furthermore, in areas where managers are willing to apply these recommendations to larger areas of the corridor, cost savings in the form of a longer vegetation control cycle (due to reduced resprouting following mid-summer cuttings) appear to be simultaneously achievable (Rea 2005).

Acknowledgments We would like to thank K. Litwinow and the many research assistants and student volunteers who worked tirelessly to collect field data. Major funding for this project was provided by the Insurance Corporation of British Columbia, British Columbia Hydro and Power Authority, British Columbia Rail and the University of Northern British Columbia. Brownridge and Company Insurance Services, Sussex Insurance Agency and Nauroth & Associates Insurance Brokers also provided financial support. O. Hjeljord, G. Hesse and four anonymous reviewers provided constructive and welcomed feedback on an earlier draft of this manuscript.

References

Alpe MJ, Kingery JL, Mosley JC (1999) Effects of summer sheep grazing on browse nutritive quality in autumn and winter. Journal of Wildlife Management 63:346–354

Bozzo JA, Beasom SL, Fulbright TE (1992) White-tailed deer use of rangeland following browse rejuvenation. Journal of Range Management 45:496–499

Bryant JP, Danell K, Provenza F, Reichardt PB, Clausen TA, Werner RA (1991) Effects of mammal browsing on the chemistry of deciduous woody plants. In: Tallamy DW, Raupp MJ (eds) Phytochemical induction by herbivores. John Wiley and Sons, New York, USA, pp 135–154

Bryant JP, Kuropat PJ (1980) Selection of winter forage by sub-arctic browsing vertebrates-the role of plant chemistry. Annual Review of Ecology and Systematics 11:261–285

Danell K, Huss-Danell K, Bergström R (1985) Interactions between browsing moose and two species of birch in Sweden. Ecology 66:1867–1878

Environment Canada (2010) Canadian climate normals 1971–2000. http://climate.weatheroffice.gc.ca/climate_normals/. Accessed April 2010

Groot Bruinderink GWTA, Hazebroek E (1996) Ungulate traffic collisions in Europe. Conservation Biology 10:1059–1067

Gundersen H, Andreassen HP, Storaas T (1998) Spatial and temporal correlates to Norwegian moose-train collisions. Alces 34:385–394

Gutteridge RC (1997) The productivity of *Tipuana tipu* under three cutting regimes in southeast Queensland. Agroforestry Systems 35:323–328

Hardesty LH, Box TW, Malechek JC (1988) Season of cutting affects biomass production by coppicing browse species of the Brazilian caatinga. Journal of Range Management 41:477–480

Härkönen S, Heikkilä R (1999) Use of pellet group counts in determining density and habitat use of moose *Alces alces* in Finland. Wildlife Biology 5:233–239

Jaren V, Andersen R, Ulleberg M, Pedersen PH, Wiseth B (1991) Moose–train collisions: the effects of vegetation removal with a cost-benefit analysis. Alces 27:93–99

Jenkins KJ, Happe PJ, Wright RG (1990) Evaluating above-snow browse availability using nonlinear regressions. Wildlife Society Bulletin 18:49–55

Kays JS, Canham CD (1991) Effects of time and frequency of cutting on hardwood root reserves and sprout growth. Forest Science 37:524–539

Klassen NA, Rea RV (2008) What do we know about nocturnal activity of moose? Alces 44:101–109

Lavsund S, Sandegren F (1991) Moose–vehicle relations in Sweden: a review. Alces 27:118–126

Machida S (1979) Differential use of willow species by moose in Alaska. Thesis, University of Alaska, Fairbanks, USA

Meidinger D, Pojar J (1991) Ecosystems of British Columbia. British Columbia Ministry of Forests Special Report Series 6, Victoria, Canada

Milliken GA, Johnson DE (1984) Analysis of messy data: vol I. Designed experiments. Van Nostrand Reinhold, New York, New York, USA

Oetting RB, Cassell JF (1970) Effects of interstate corridor mowing on wildlife, snow buildup, and motorist opinion in North Dakota: a preliminary report. National Research Council, Highway Research Board, Report Number IRN10063353

Peek FW, Bellis ED (1969) Deer movements and behaviour along an interstate highway. Highway Research News 36:36–42

Penner DF (1978) Some relationships between moose and willow in the Fort Providence, N.W.T. area. Thesis, University of Alberta, Edmonton, Canada

Porter GL (1990) Willow species of disturbed sites in the S.B.S. zone in north-central B.C. British Columbia Ministry of Forests, FRDA handbook 004, Victoria, Canada

Puglisi MJ, Lindzey JS, Bellis ED (1974) Factors associated with highway mortality of white-tailed deer. Journal of Wildlife Management 38:799–807

Rea RV (1999) Response of Scouler's willow (*Salix scouleriana*) to mechanical brushing: implications to the quality of winter browse for Moose (*Alces alces*). Thesis, University of Northern British Columbia, Prince George, Canada

Rea RV (2003) Modifying roadside vegetation management practices to reduce vehicular collisions with moose (*Alces alces*). Wildlife Biology 9:81–91

Rea RV (2005) The influence of brush-cutting time on plant resprouting and attractiveness to herbivores: implications for road and rail side vegetation management. Unpublished Report. Prince George, BC, Canada

Rea RV, Child KN, Spata DP, MacDonald D (2007) Influence of cutting time on brush response: implications for herbivory in linear (transportation) corridors. Environmental Management 40:219–230

Rea RV, Gillingham MP (2001) The impact of the timing of brush management on the nutritional value of woody browse for moose (*Alces alces*). Journal of Applied Ecology 38:710–719

Regelin WL, Schwartz CC, Franzmann AW (1987) Effects of forest succession on nutritional dynamics of moose forage. Swedish Wildlife Research Supplement 1:247–263

Renecker LA, Schwartz CC (1998) Food habits and feeding behaviour. In: Franzmann AW, Schwartz CS (eds) Ecology and management of the North American moose. Smithsonian Institution Press, Washington, DC, USA, pp 403–439

Risenhoover KL (1987) Winter foraging strategies of moose in subarctic and boreal forest habitats. Dissertation, Michigan Technical University, Houghton, USA

Schwab FE, Pitt MD (1987) Comparison of a direct and an indirect method for estimating available winter browse. Wildlife Society Bulletin 15:544–549

Shipley LA, Gross JE, Spalinger DE, Hobbs NT, Wunder BA (1994) The scaling of intake rate in mammalian herbivores. American Naturalist 143:1055–1082

Sielecki LE (2000) WARS wildlife accident reporting system 1999 annual report (1995–1999 synopsis). British Columbia Ministry of Transportation and Highways, Victoria, Canada

Sokal RR, Rohlf FJ (1995) Biometry: the principles and practice of statistics in biological research, 3rd edn. W.H. Freeman, New York, New York, USA

Van Horne B (1983) Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893–901

Zar JH (1984) Biostatistical analysis, 2nd edn. Prentice Hall, Englewood Cliffs, New Jersey, USA