EFFECTS OF CONIFER RELEASE WITH HERBICIDES ON MOOSE: BROWSE PRODUCTION, HABITAT USE, AND RESIDUES IN MEAT

R. A. Lautenschlager

VMAP, Ontario Forest Research Institute, P.O. Box 969, 1235 Queen St. East, Sault Ste. Marie, Ontario P6A 5N5

ABSTRACT: Six studies, 5 in spruce plantations and 1 in a naturally regenerated spruce-fir stand, have examined the effects of conifer release with herbicides on moose browse production and habitat use. Both were reduced in plantations and naturally regenerated spruce-fir stands for up to 4 growing seasons after treatment. Only 1 study, in a naturally regenerated stand, examined long-term effects, and there forage production on all treated areas exceeded production on controls 8 growing seasons after treatment. Although feeding studies and residues in digestive tracts show that animals consume some glyphosate while feeding, herbicides were not found in the flesh of game animals (moose, deer, hare) taken from within or near areas released with glyphosate.

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Herbicides have been used to manage northern coniferous forests (McConkey 1958) and large-game habitat (Krefting *et al.* 1956) for nearly half a century. During the late 1970s and 1980s, however, their use increased dramatically (Kuhnke and Brace 1986, Maass 1989); this, coupled with increasing public concern about chemicals in the environment, stimulated controversy between concerned publics and forest managers (Bledsoe 1981, McCormack 1981, Campbell 1990), as well as among foresters, biologists, and ecologists. Because the response of wildlife to herbicides used in forestry has become a concern, I have periodically reviewed studies that examined the effects of these treatments (Lautenschlager 1986, 1991, 1992). Here I specifically review studies of the effects of conifer release with herbicides on moose (*Alces alces*) (1) browse production, (2) habitat use, (3) forage quality, and (4) potential contamination of flesh.

REVIEW ANALYSIS

Browse Production and Habitat Use

Six studies (Table 1) have examined the effects of conifer release with herbicides on moose browse (deciduous woody forage) and habitat use.

Kennedy and Jordan (1985) and Kennedy (1986), working in northern Minnesota, compared the effects of 2,4-D and glyphosate applied to 4-17-year-old spruce plantations on moose forage production and use. Kennedy (1986) concluded that, 1 growing season after treatment, glyphosate-treated areas contained about 1/2 the available browse biomass of areas treated with 2,4-D and about 1/4 the browse biomass found on "control" areas (areas scheduled for treatment 2-4 years after the herbicide treatments were applied). In addition, she found that during the summer following treatment moose browsed more in the 2,4-D-treated plantations than in the glyphosate-treated plantations.

Connor and McMillan (1988), working in northwestern Ontario, examined moose winter use of areas planted with spruce 1-4 growing seasons before treatment with glyphosate. They report that treated and control plots had similar numbers of tracks during the first 2 winters after treatment, but that in the third winter more moose tracks were observed on the control areas. Pellet group surveys also showed that winter moose presence was 3 times greater on control plots during the third winter. Moose track aggregates (areas of concentrated feeding activity) were more numerous on control than treated plots during the first and second winters after treatment, and available browse was 4 times greater on con-

Table 1. Overview of studies of the effects of herbicides used for conifer release on moose browse and habitat use.

Authors and publication date	Herbicide(s) studied	Years since cutting and/or planting	Post-treatment growing season(s) studied	Pre-treatment data collected	Moose survey method	Vegetation data collected
Connor & McMillan (1988)	glyphosate	3-12 cutting 1-4 planting	1, 2	none	track & pellet group counts	available browse
Cumming (1989)	glyphosate	a) 5 & 6 cutting and planting b) 2 cutting	1	available browse & winter browse use	winter browse use	stem counts and biomass estimates
Hjeljord & Grønvold (1988)	glyphosate	4-7 cutting 3-6 planting	1, 2	available browse & winter browse use	pellet group counts	available browse
Kennedy (1986)	2,4-D & glyphosate	4-17 cutting and planting	1-4	none	none	available browse & browse use
Newton *et al.* (1989)	2,4-D 2,4,5-T, glyphosate, & triclopyr	7 cutting (natural regeneration)	1, 8	available browse	none	available browse

trol than treated plots 2 growing seasons after treatment.

In southern Norway, Hjeljord and Grønvold (1988) examined browse production, browsing, and habitat use on glyphosate-released, hand-cut-released, and control plots in 3 areas that had been planted with spruce 3-6 years before treatment. They report that: (1) browse production on cut areas increased rapidly during the 2 growing seasons after cutting, (2) browse production increased slowly on control plots, and (3) browse production on the glyphosate-treated areas was negligible for 2 growing seasons after treatment. Moose pellet group counts were also lower on the glyphosate-treated areas during that time.

In northwestern Ontario Cumming (1989) examined browse production and browsing during the growing season before and after glyphosate was used to release conifers (5 years after planting) in 1 area, and for site preparation in another area. In the release area, he concluded that treatments provided satisfactory silvicultural release but reduced available browse by 5-41% depending on the treatment block. Browsed stems/ha decreased by 15-82% on released areas, and increased by 130-3200% on controls. However, sample variability was so great that significant differences were not found between released and control areas. In the site preparation area, the glyphosate treatment reduced available browse by 63-92%.

In east-central British Columbia, Lloyd (1989, 1990*a,b*) examined the effects of hexazinone and glyphosate treatments on production and use of moose browse. She found that browsing on all areas, including controls, was reduced during the winter after treatment. Three growing seasons after treatment moose use was approximately 8 times higher on control areas, where willow density was twice that of treated plots. She also found a significant difference in resistance to glyphosate treatment among browse species and recommended that effects on browse may be minimized by using lower application rates and treating single areas in sections over time. She concluded that conifer release did diminish moose habitat quality and use, but that the decrease in use was not solely correlated with browse abundance.

In north-central Maine, Newton *et al.* (1989) examined the effects of glyphosate, triclopyr, and phenoxy herbicides, applied 7 years after "clear-cutting", on browse production in a naturally regenerating spruce-fir area. One growing season after treatment the phenoxies (2,4,5-T and combinations of 2,4,5-T and 2,4-D) reduced available browse by an average of 22%, while glyphosate and triclopyr applications reduced it by an average of 46% (Table 2). Available browse had also decreased on control plots by an average of 35%, because untreated deciduous species, mainly aspen (*Populus* spp.), were growing above the reach of browsers on these plots.

Eight growing seasons after treatment the plots were re-examined, and available browse was still reduced on all plots including the controls, which had 92% less available browse than at the time of treatment. Available browse on phenoxy-treated, and glyphosate- or triclopyr-treated plots at this time averaged 61.3 and 58.6% less, respectively, than at the time of treatment (Table 2). Phenoxy-treated plots contained 3.1 - 7.0 times as much available browse as did control plots, and browse availability on glyphosate- and triclopyr-treated plots, although more variable, was similar, ranging between 3.2 and 7.4 times as much as that found on control plots.

Forage Palatability and Nutrient Content

Lloyd (1989) reports that moose browse herbicide-damaged plants when damage is light or moderate, but they do not browse severely damaged or dead plants. Sullivan and Sullivan (1979) fed captive black-tailed deer (*Odocoileus hemionus*) both control and glyphosate-treated forage, and found that deer showed no preference. Campbell *et al.* (1981) also found that when applied at silviculturally effective rates, black-tailed deer do not avoid foliage treated with 2,4-D, 2,4,5-T, atrazine, dalapon, fosamine, or glyphosate.

Few studies have specifically examined forage quality following herbicide treatments (Balfour 1989). Morgan and McCormack (1973), however, report that 2 growing seasons after 3-year-old balsam fir transplants were planted, simazine-treated transplants had approximately twice the crude protein, plus higher ash and moisture levels than control and fertilized transplants. Environmental resources [light, moisture, and nutrients (Smith *et al.* 1988, Kimmins *et al.* 1989)] increase rapidly soon after conifer release with herbicides. The same resources which contribute to increased crop tree growth (Walstad and Kuch 1987, Newton *et al.* 1992) also become available to and are used by the remaining, re-emerging, and invading angiosperms (potential browse). Therefore, when compared to untreated areas, browse on treated areas may be of superior quality, i.e., with increased digestibility and protein content.

Effects on Forage Consumption and Meat Quality

Because some moose in recently released areas are likely to consume herbicide residues, the possibility of secondary effects on human consumers must be considered. Legris and Couture (1991) examined a variety of samples from snowshoe hare (*Lepus americanus*), moose, and white-tailed deer (*O. virginianus*) shot inside or close to areas that had been treated with glyphosate approximately 2

Table 2. Percent deciduous cover (by treatment and height stratum) before and one and eight growing seasons after aerial herbicide application to a naturally regenerated spruce-fir stand, seven years after a winter clearcut in north central Maine. (After Newton *et al.* 1989)

Herbicide (kg/ha)	Pretreatment			One growing season post-treatment			Percent reduction from pre-treatment	Eight growing seasons post-treatment					Percent reduction from pre-treatment
	<1.5m	>1.5m	Total	<1.5m	>1.5m	Total	<1.5m	<1.0m	1.0-2.5m	<1.5m[1]	>2.5m	Total	<1.5m
2,4,5-T (2.2)	39	48	87	31	16	47	21	9	7	11.3	43	59	71
2,4, 5-T (3.3)	59	26	85	45	2	47	24	16	7	18.3	10	33	69
2,4-D(1.1) + 2,4,5-T(1.1)	47	31	78	40	2	42	15	9	14	13.7	16	39	71
2,4-D(2.2) + 2,4,5-T(2.2)	39	42	81	29	7	36	26	20	17	25.7	29	66	34
Glyphosate (1.65)	58	38	96	28	10	38	52	11	2	11.7	10	23	80
Glyphosate (3.3)	60	68	128	34	<1	35	43	23	13	27.3	11	47	55
Triclopyr (2.2)	36	40	76	30	1	31	17	19	22	26.3	9	50	27
Triclopyr (4.4)	43	27	70	11	0	11	74	17	4	18.3	7	28	57
Triclopyr (2.2) +2,4-D(2.2)	65	34	99	38	3	41	42	14	6	16.0	5	25	75
Control	46	38	84	30	55	85	35	3	2	3.7	105	110	92

[1]Modified from Newton *et al.* (1989)

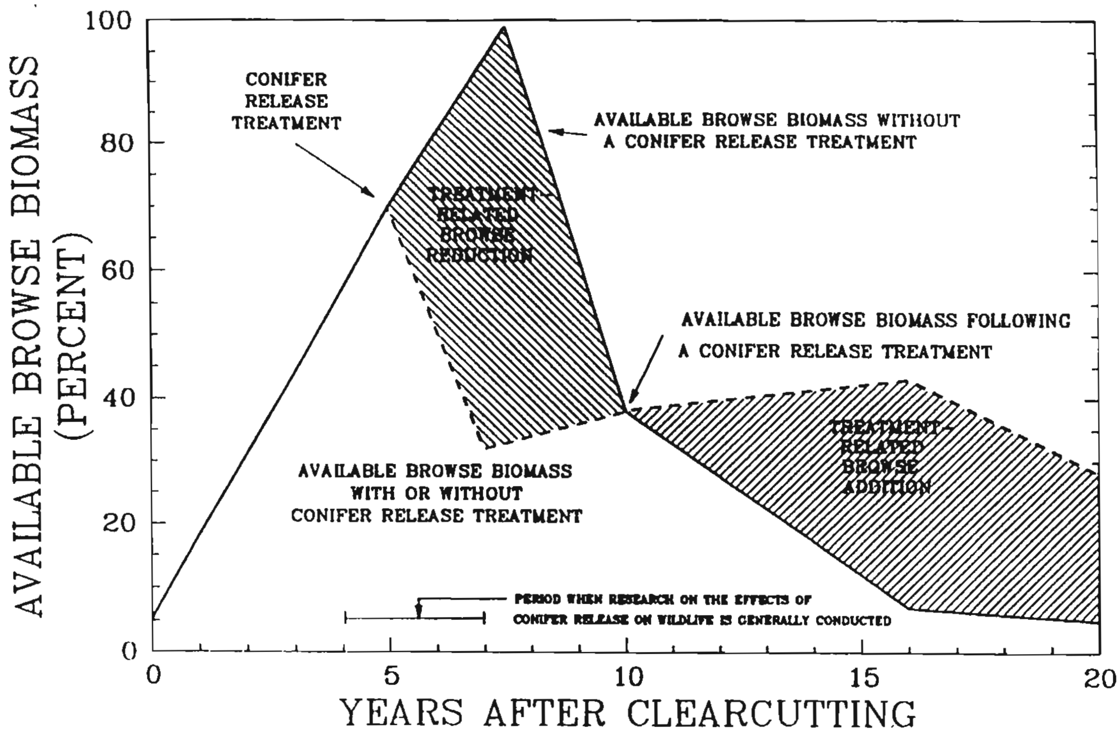

Fig. 1. Percent deciduous cover 0-1.5m above ground (available browse) by treatment in north-central Maine.

months before sampling. Although a positive value (0.146 µg/g) was found in 1 moose flesh sample they state that this was likely due to contamination (the sample was apparently covered with moose hair), and note that the 31 other samples showed no detectable residues. Based primarily on data from snowshoe hare, they conclude that glyphosate ingested with vegetation is mainly eliminated through the urinary and fecal tracts, and that the risk of contamination from the consumption of meat, or organs such as liver, from game animals which have fed in or near treated areas is very low. Still, the authors advise cautious field preparation of animals taken from in or near treated areas to minimize potential exposure to herbicide residues.

CONCLUSIONS

In the studies examined, browse production and moose habitat use decreased for between 1 and 4 growing seasons after treatment. Only Newton *et al.* (1989) examined browse production beyond 4 growing seasons after treatment. An analysis of those data, collected 8 years after treatment, shows that because untreated vegetation gradually grew beyond the reach of browsers, browse production on treated plots was 3-7 times greater than on control plots. Newton *et al.* (1989) also suggest that thinning young naturally regenerated conifers, approximately 10 years after release, will provide additional years of browse production on treated areas, and that when these released forage-producing young stands are intermingled with older stands they offer a variety of foods and covers.

The problem with comparing conclusions based on the work by Newton *et al.* (1989) with other studies is that Newton *et al.*'s work was in naturally regenerated spruce-fir stands, while the other studies were conducted in plantations. In addition that area was treated 7 years after cutting, while other studies exam-

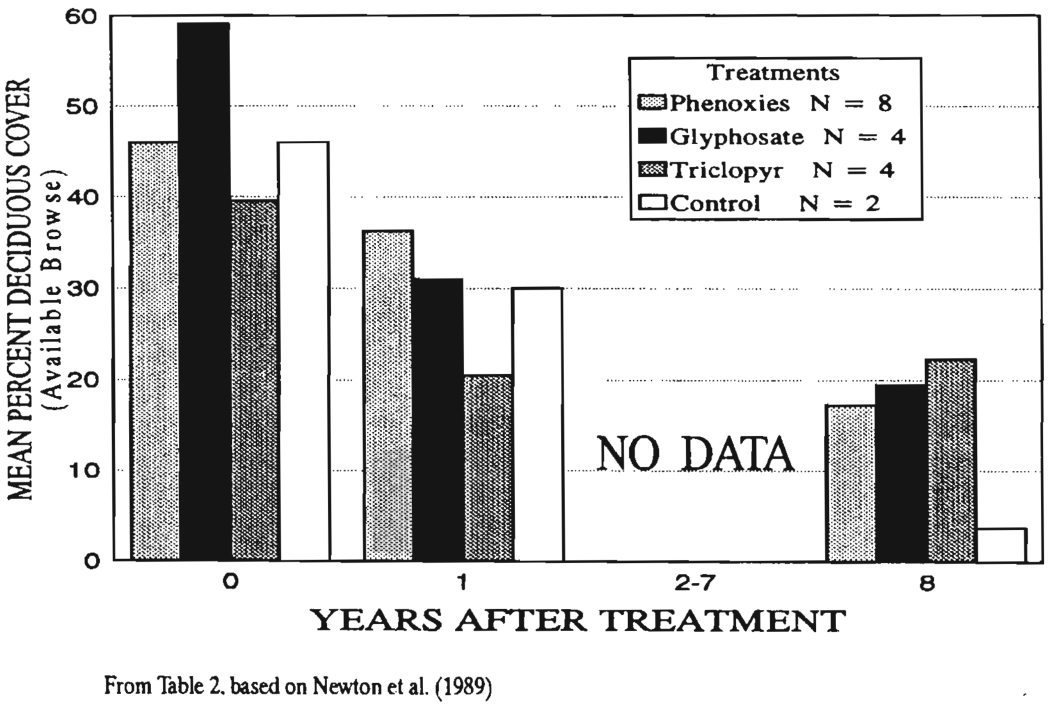

Fig. 2. Projected growth and available browse biomass with and without conifer release treatments in naturally regenerated spruce-fir (*Picea-Abies*) forests.

ined areas treated sooner after cutting. Therefore assuming that conifer release will consistently lead to long-term increased browse production on treated versus control areas is questionable. General successional patterns, however, suggest that the initial drop in deciduous cover and available browse on treated areas will be offset by increases over control areas several years later (Figure 2). In these situations conifer release with herbicides may reduce the "boom and bust" in forage availability that moose often experience following other forest disturbances. Jordan (Pers. Comm.), however, argues that in certain instances moose can keep browse within reach for 20 years, and in southern Norway Hjeljord and Grønvold (1988) state that moose browsing "relieves the spruce seedlings on our clearcuts from considerable competition by hardwoods". It seems, however, that few areas have moose populations high enough to accomplish this.

There is clearly a need for more studies that examine (1) long-term effects of conifer release with herbicides on moose foods, (2) moose habitat use of treated areas at times other than winter, and (3) browse quality following treatment. Studies of short-term effects have convincingly shown that conifer release treatments reduce the value of treated habitat for several years after treatment, but the only study available which examined long-term effects indicates that initial browse reductions in treated areas are balanced by longer-term additions when compared to controls. Clearly, studies of long-term effects will require appropriate pre-treatment information on available forage and moose use, and appropriate controls; these are lacking in many previous studies.

Regardless of the effects of any forest management practice on a wildlife group, those effects must be examined in relation to the surrounding forest landscape. Management practices that lead to large early successional stands in the midst of older successional stands may be desirable, while practices which simply add 1 more early successional stand to an abundance of such stands would seem less desirable. Therefore forest management practices in general, and the effects of conifer release with herbicides in particular, must be examined in relation to the forest landscape mosaic. What may be unacceptable in certain areas may be desirable in others, depending on how it fits into the present or developing forest landscape pattern.

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