Effects of conifer release with glyphosate on summer forage abundance for deer in Maine

J.K. Vreeland, F.A. Servello, and B. Griffith

Abstract: Effects of conifer release with glyphosate on summer forage availabil'ty for large herbivores in northern forests have received relatively little study. We determined effects of glyphosate treatment of clearcuts on abundance ot summer foods for white-tailed deer *(Odocoileus virginianus)* at 1 and 7-10 years posttreatment. We measured the abundance (percent cover in a 0- to 1.8-m height stratum) of five forage classes for deer (leaves of deciduous trees, leaves of deciduous shrubs, forbs, grasses, ferns) on 12 clearcuts (six treated, six untreated) to determine 1-year effects and on 10 clearcuts (five treated, five untreated) to determine 7- to 10-year effects. Abundance of leaves of deciduous trees was greater on untreated sites (38 versus 11%) at 1 year posttreatment, but the difference was less (18 versus 12%) at 7-10 years posttreatment (age x treatment interaction, $P = 0.005$). Leaves of deciduous shrubs exhibited a similar pattern. Abundance of forbs was similar (13-14%) at 1 year posttreatment but greater on treated sites (29 versus 15%) at 7-10 years posttreatment ($P = 0.03$). Grasses and ferns were less abundant than other forase clas.->es. Overall, glyphosate application initially decreased the abundance of leaves of deciduous trees and shrubs used as food in summer, but the longer term positive effects on forb abundance may result in little net change in overall habitat value.

Resume : Les effe'.s du denotement des coniferes a 1'aide du glyphosute stir la disponibilite de nourriture pour les grands herbivores de.v tbrets nnrdiques ont ete relativement peu etudies. Nous avons determine les effets du traitement de parterres de coupe au glyphosate sur 1'abondance de nourriture estivale pour le cerf de Virginie *(Odocoileus virginianus)* 1 an et 7-10 ans apres le traitement. Nous avons mesure 1'abondance (pourcentags de recouvremer.t dans unc jtrate de hauteur de 0 a 1.8 m) de cinq classes de nourriture pour le cerf (feuilles d'arbres decidus. feuilles d'arbustes decidus. plantes herbacees dicotyledones, graminees et fougeres.) dans 12 parterres de coupe (6 traites. 6 non traites) afin de determiner les effets apres 1 an et dans 10 parterres de coupe (5 traites. 5 non traites) afin de determiner les effets apres 7-10 ans. L'abondance des feuilles d'arbres decidus etait plus grande dans les sites non traites (38 versus 11%) apres 1 an, mais la difference etait moindre apres 7-10 ans (18 versus 12%; interaction age x traitement, $P = 0.005$). Les feuilles d'arbustes decidus presentaient un patron similaire. L'abondance des plantes herbacees dicotyledones etait similaire (13-14%) apres 1 an. mais plus grande dans les sites traites (29 versus 15%) apres 7-10 ans ($P = 0{,}03$). Les graminees et les fougeres etaient moins abondantes que les autres types de nourriture. En general, 1'application de glyphosate a diminue 1'abondance initiale des feuilles d'arbres et arbustes decidus utilisees comme nourriture estivaie. mais le changement net dans la valeur generate de 1'habitat risque d'etre negligeable etant donne les effets positifs a long terme sur 1'abondance des plantes herbacees dicotyledones.

[Traduit par la Redaction]

Introduction

Glyphosate is frequently applied in several herbicide formulations to regenerating clearcuts and plantations in Maine and other northern forested regions to suppress vegetation competing with preferred conifer species (McCormack 1994; Sullivan and Sullivan 1997). Public concern about the environmental and ecological effects of herbicide use has resulted in an increasing intensity of research on the silvicultural use of glyphosate (Campbell 1990; Lautenschlager et al. 1997; Sullivan and Sullivan 1997). Vertebrate studies have focused on small mammals, songbirds, and moose *(Alces alces)* (Lautenschlager 1993). In Maine, there is concern that herbicide use for forest management is having a negative effect on deer populations by reducing their food resource. Research on moose habitat has examined the effects of glyphosate on winter browse availability and habitat use (Connor and McMillan 1988: Gumming 1^89: Raymond et al. 1996) because moose commonly feed in ciearcut areas in winter (Teller 1967, 1970). In contrast, \\hiie-tailed deer *(Odocoileus virginianus)* avoid clearcut or open areas in winter because of deep snow (Teller 1967, 1970; Monthey 1984) but use these habitats during spring and summer (Kohn and Mooty 1971; Drolet 1976, **1978: Nelson** 1979).

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Therefore, short-term effects of glyphosate use on deer habitat in northern regions should primarily occur during the growing season.

In northern forested regions, diets of white-tailed deer consist primarily of forbs and leaves of deciduous plants, with lower and less consistent use of grasses, ferns, and fungi (Table 1; Kohn and Mooty 1971; McCaffery et al. 1974; Skinner and Telfer 1974; Stormer and Bauer 1980; Crawford 1982; McCullough 1985; Heim 1988). In conifer release treatments, spray solutions containing the active ingredient glyphosate can damage or kill a substantial amount of nonconifer vegetation (Newton et al. 1992; Freedman et al. 1993; Bell et al. 1997) and therefore has the potential to negatively affect summer food resources for deer. Newton et al. (1989) and Raymond et al. (1996) have demonstrated that effects on wildlife habitat may be quite different at longer time scales (7-11 years posttreatment) than shorter time scales (<4 years). The objectives of this study were to determine the effects of glyphosate used for conifer release on the availability of summer foods for white-tailed deer in naturally regenerating clearcuts in Maine at 1 and at 7-10 years posttreatment. We hypothesized that treatment would initially reduce the abundance of major forages classes but that forage classes would exhibit varying levels of recovery and abundance in the longer term on the subsequently conifer-dominated sites.

Study area

Our study area was located in western and central Maine in northern Somerset and Piscataquis counties. The region is primarily commercial forestland. characterized by a mosaic of clearcuts, regenerating cuts, and unharvested stands. Study sites were in the spruce (*Picea* spp.) - balsam fir (*Abies balsamea* (L.) Mill.) and northern hardwood forest type (Westvald et al. 1956) and consisted of 22 regenerating clearcuts. Balsam fir. spruce, red maple (*Acer rubrum* L.), paper birch (*Betula papyrifera* Marsh.), pin cherry (*Prunus pensylvanica* L.f.). aspen (*Populus* spp.), and eastern white pine (*Pinus strobus* L.) were common tree species. Raspberry (*Rubus* spp.) and blueberry (*Vaccinium* spp.) predominated in the shrub layer. Canada mayflower (*Maianthemum canadense),* clintonia (*Clintonia borea/is),* fireweed (*Epilobium angustifolium),* sorrel (*Oxalis montana),* and twinflower (*Linnaea borealis)* were common herbaceous species. Additional information on the study sites is presented in Raymond et al. (1996).

Methods

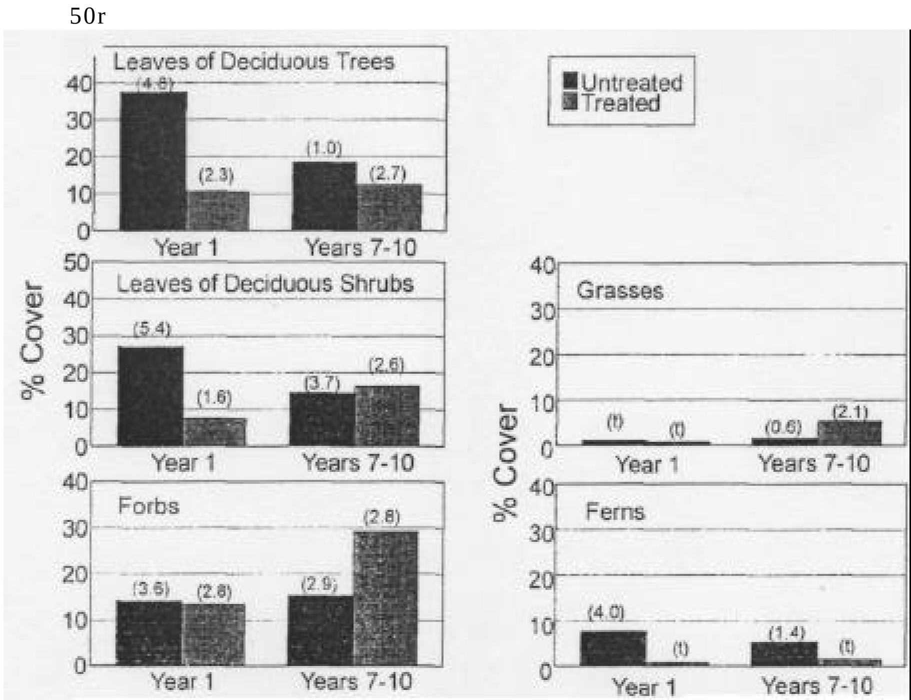
Effects of glyphosate at 1 year posttreatment were studied by comparing six treated clearcuts (23-90 ha) with six untreated clearcuts (18-52 ha) that were harvested between 1983 and 1985. Deciduous tree cover was dominant on these clearcuts and was approximately 1-2 m in height (Eschholz et al. 1996). These 12 clearcuts were selected the year prior to treatment and were similar in vegetative structure. Clearcuts were paired based on vegetative composition (woody dominants) and location to further reduce potential biases, and one clearcut from each pair was randomly selected for aerial treatment with glyphcsate in August 1991. We used a relatively large number of randomly assigned study sites rather than pretreatment sampling. However, previously reported data for these sites showed that mean woody browse biomass in winter and tree species densities did not differ between these treatment groups during the growing season prior to treatment (Eschholz et al. 1996: Raymond et al. 1996).

Table 1. Percent composition[a] of spring and summer diets of white-tailed deer in northern forested habitats of the central and eastern U.S. and eastern Canada.

	Forbs[b]		Leaves of deciduous plants[c]		Grasses		Ferns		Fungi		Fruit	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
Maine[d]	55	16	5	46	0	0	5	2	0	0	0	7
New Brunswick[e]	33		37		4		1		14		0	
New Hampshire[f]	41		28		0		0		0		23	
Michigan[g]		25		61		2		7		0		5
Minnesota[h]		25		63		5		0		7		0
Wisconsin[i]	26	15	6	37	17	4	0	0			5	1

Note: t, trace (<1%).
[a]We excluded woody twig, sedge, and miscellaneous categories. Also, some studies did not identify all food material.
[b]Nonwoody species. Most common were clintonia and Canada mayflower.
[c]Woody species. Most commonly includes maple spp., aspen spp., northern bush honeysuckle, wild raisin, and paper birch.
[d]Crawford (1982). Tame deer field study.
[e]Skinner and Telfer (1974). Rumen analysis. Values estimated from Fig. 1. Summer is June and July. Grasses include sedges.
[f]Heim (1988). Tame deer field study. Fruits were acorns.
[g]Stormer and Bauer (1980). Tame deer field study.
[h]Kohn and Mooty (1971). Rumen analysis.
[i]McCaffery et al. (1974). Rumen analysis. Leaves of deciduous plants include small proportion of white cedar (*Tsuga* spp.). Fruits include small proportion of mushrooms.

Fig. 1. Abundance (% cover) of leaves of deciduous trees, leaves of deciduous shrubs, forbs, ferns, and grasses on glyphosate-treated and untreated clearcuts at 1 and 7-10 years posttreatment in northern Maine. June-August 1993. Standard errors are given in parentheses.



Treated sites were aerially sprayed with glyphosate (1.65 kg-ha ' acid equivalents in the form of Roundup®) in August 1991. At the start of sampling (June 1992), the mean number of years since harvest was 6.8 and 5.8 for the treated and untreated sites, respectively. Effects at 7-10 years posttreatment were studied using five treated clearcuts (21-63 ha) and five untreated clearcuts (21-73 ha) that were harvested between 1969 and 1979. Clearcuts were selected from forest cover and management maps. Selection criteria included having similar harvest histories and occurrence on upland sites. Soil types were similar among treatment groups (C. Haag, personal communication). Conifer cover dominated older treated clearcuts whereas deciduous trees dominated untreated clearcuts (Eschholz et al. 1996). These older treated clearcuts were aerially sprayed with glyphosate (1.65 kg-ha~' acid equivalents as Roundup®) between 1983 and 1985. At the start of sampling (June 1992), the mean number of years since harvest was 16.3 and 19.9 for the treated and untreated sites, respectively. We did not consider this small age difference important because, by age 16, untreated stands on these site types are essentially closed canopied above 2.5 m (Newton et al. 1989: personal observation on present study sites), indicating that environmental conditions in the lower strata are similar during that age period.

Because there is a clear and consistent pattern of high use of forbs by deer in the spring and leaves of deciduous plants and forbs in the summer in northern regions (Table 1), we measured forage abundance by forage class (leaves of deciduous trees, leaves of deciduous shrubs, forbs, grasses, ferns). Measurements were made by species, but data were compiled by forage class. We used ocular estimates of percent cover as an index of forage abundance. Percent cover of leaves of deciduous trees and shrubs <1.8 m tall was ocularly estimated to 10% intervals by species within 40 sample plots 2 x 5 m located 50 m apart on parallel transects systematically distributed on each clearcut. Percent cover of vegetation in the ground stratum (forbs, grasses, ferns) was measured with a sighting tube (Noon 1980) at 0.5-m intervals on two parallel 5-m transects in each plot (20 points per plot). Unharvested parts of clearcuts, open water, boulder fields, and gravel pits were not sampled. All measurements were made during June-August 1992.

We tested for differences in abundance of forage classes by treatment, stand age (years since treatment), and age x treatment interaction using a nested analysis of variance (Zar 1984, p. 258) using SYSTAT (Wilkinson 1992). The error term was clearcut sites nested within treatment and age (df = 18). We used an alpha of 0.10 to reduce the probability of a type II error (failure to reject the null hypothesis of no effect from glyphosate treatment when it is false).

Results

Abundance (percent cover) of leaves of deciduous trees was greater on untreated clearcuts ($P < 0.001$) and on younger clearcuts ($P = 0.014$) (Fig. 1). There was an age x treatment interaction: deciduous leaf availability was several times greater on untreated than on treated clearcuts (38 versus 11%) at 1 year posttreatment, but the difference was less (18 versus 12%) at 7-10 years posttreatment ($P = 0.005$). Abundance of leaves of deciduous shrubs was greater on untreated than on treated clearcuts (27 versus 8%) at 1 year posttreatment but was similar on clearcuts at 7-10 years posttreatment (15 versus 17%) (age x treatment interaction, $P = 0.01$) (Fig. 1). Abundance of forbs was similar on treated and untreated clearcuts (13-14%) at 1 year posttreatment and on untreated clearcuts at 7-10-years posttreatment whereas forbs were approximately twice as abundant on older treated clearcuts (age x treatment interaction. $P = 0.03$) (Fig. 1). Abundance of grasses was low (<6%) but exhibited a pattern similar to that of" forbs with little difference for younger clearcuts and greatest abundance on older treated clearcuts (age x treatment interaction, $P = 0.05$) (Fig. 1). Ferns were more abundant on untreated clearcuts ($P = 0.03$) but did not differ with age ($P = 0.69$), and there was no interaction ($P = 0.52$).

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Discussion

Glyphosate application initially reduced the abundance of the deciduous leaf forage class approximately 70%; however, at 7-10 years, deciduous leaf abundance did not differ between treatments. We believe that this was due to regeneration on glyphosate-treated clearcuts and a decline in abundance of browse on untreated sites as deciduous plants grew out of reach of deer, which is the general response to herbicides described by Newton et al. (1989). Our results were generally similar to Newton et al.'s (1989) results for a similar glyphosate treatment in which they reported greater deciduous cover in treated than in untreated plots at 9 years posttreatment in a stratum <1.0 m and no difference in the 1.0- to 2.5-m stratum. Mean deciduous cover values at <1.0 m (2 and 11%) and at 1.0-2.5 m (2%) were all low, suggesting that overall browse abundance was similar for treated and untreated sites, as in the present study.

Most of the deciduous leaf forage class available to deer was composed of known foods of white-tailed deer in Maine, and therefore, treatment-induced patterns in this forage class represent changes in food abundance. Maple species, white birch, and aspen species, which are used in summer by deer in Maine (Crawford 1982; Crawford et al. 1993), comprised 65-85% of the mean deciduous tree cover on the four treatment-age site classes (unpublished data). Region-wide, a diversity of deciduous trees are used by deer, but aspen and maple are consistently reported in summer diets (Kohn and Mooty 1971; Skinner and Telfer 1974; Stormer and Bauer 1980; Crawford 1982: Heim 1988), indicating that our results on food abundance are broadly applicable.

Response of forb abundance to treatment was distinctly different than for deciduous cover. Forb abundance was not affected at 1 year posttreatment, and we observed significantly greater abundance of forbs on treated than on untreated clearcuts at 7-10 years posttreatment. Our results are generally similar to other studies directly applicable to this region. For instance, Bell et al. (1997) reported increased forb and grass abundance in the first year after glyphosate treatment in Ontario. Other researchers reported that silvicultural use of glyphosate generally reduces the cover of all nonconifer species at least temporally (Freedman et al. 1993; Horsley 1994), but Freedman et al. (1993) noted that individuals of many ground species (including mayflower, which was common on our sites) survived treatment, presumably because taller canopy plants shielded them from the spray (Lautenschlager 1993). They also noted that other herbaceous species vigorously regenerated from wind-dispersed seed in the first growing season. Initial effects on forbs and other ground cover may be influenced by spray conditions, canopy development after treatment, environmental conditions for recolonization, and other factors (see Lautenschlager 1993).

The initial effect on forb abundance is probably less important for deer than the subsequent posttreatment pattern of abundance. We observed substantially greater forb abundance on older treated sites. Newton et al. (1992) also reported that herbaceous cover was greater on herbicide-treated than on control plots in Maine for several herbicides including-glyphosate and in studies of hardwood sites in Pennsylvania, and Horsley (1994) found greater grass and sedge cover (other herbaceous cover did not occur or was not measured) on treated than on untreated sites 2. 4. and 9 years posttreatment. This greater abundance of forbs and grasses on treated sites is likely due to the reduction in deciduous trees and shrub cover and the incomplete canopy closure by confiers 7-10 years posttreatment (Freedman et al. 1993).

The forb forage class represents an important food resource for deer in Maine and in northern forested regions. In Maine, clintonia and mayflower may account for more than 50% of all plant biomass eaten in late spring (Crawford 1982), and mayflower, clintonia, fireweed, and sorrel were the major occurring forb species on our sites. High use of mayflower in the spring and summer has also been reported in New Brunswick (Skinner and Telfer 1974) and New Hampshire (Heim 1988), and use of clintonia has also been reported in Wisconsin (McCaffery et al. 1974). These forbs may have a relatively high importance for deer because they are used during the early spring period when other forage classes (leaves of deciduous plants and mast) are not available or are less common (Heim 1988). Therefore, the extended period of increased forb abundance on treated clearcuts may represent a significant benefit for deer.

In conclusion, we found no clear evidence that a single glyphosate treatment to clearcuts reduced summer forage abundance for deer over the longer term, as might be expected. Abundance of deciduous leaves as potential forage was reduced in the first year posttreatment, but forb abundance was unchanged. In contrast, at 7-10 years posttreatment. deciduous leaf abundance was similar on treated and untreated sites whereas forb abundance was considerably greater on treated than on untreated clearcuts, suggesting that treatment may improve the value of older regenerating clearcuts as foraging sites during the spring. As Raymond et al. (1996) suggested for management of winter browse supplies for moose, we believe that interspersion of recent and older treated clearcuts with untreated sites scheduled for future treatment is a conservative approach for minimizing large fluctuations in spring and summer forage abundance for local deer populations.

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