WINTER USE OF GLYPHOSATE-TREATED CLEARCUTS BY MOOSE IN MAINE

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Abstract: Aerial treatment of naturally regenerating clearcuts with the herbicide glyphosate initially reduces the availability of deciduous browse, but may subsequently improve bedding cover for moose *(Alces alces)*. However, the potential effects of these vegetative changes on use of clearcuts by moose has received little study. We studied effects of glyphosate treatment of clearcuts in Maine on (1) use of clearcuts by moose and (2) conifer cover during 2 periods, 1-2 and 7-11 years posttreatment. We made counts of moose tracks, beds, and pellet groups on transects in treated and untreated clearcuts in January-March 1992 and 1993 and measured conifer densities in January-March 1991-93. At 1 and 2 years posttreatment, tracks of foraging moose were 57 and 75% less abundant on treated than untreated clearcuts (P = 0.013). Counts of moose beds, total tracks, and pellet groups exhibited similar patterns as tracks of foraging moose but did not differ ($P > 0.1$) between treatments. At 7-11 years posttreatment, tracks of foraging moose (P = 0.05) and moose beds (P = 0.06) were greater on treated than untreated clearcuts. Conifer densities at 1-2 years posttreatment were not affected ($P > 0.1$) by treatment, but conifers 2.0-2.9 m tall were 2 times more abundant ($P < 0.1$) on treated than untreated clearcuts at 7-11 years posttreatment. Less foraging activity at 1-2 years posttreatment appeared to be the result of reduced browse availability because conifer cover for bedding was similar on treated and untreated clearcuts. We hypothesized that greater counts of tracks of foraging moose on older treated clearcuts was due to increased foraging activity on sites with more abundant conifer cover.

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Regenerating clearcuts are important winter foraging habitat for moose in northern coniferous forests (Telfer 1970, Monthey 1984). Use of herbicides to promote conifer regeneration on these sites decreases deciduous browse availability, but greater conifer density and height may improve cover for bedding and foraging by moose in winter. Aerial application of glyphosate, the most commonly used herbicide in northern coniferous forests (McCormack 1994), reduces deciduous browse availability on clearcuts about 70% by the second winter posttreatment (Raymond et al. 1996). Responses of moose to glyphosate-induced changes in habitat on clearcuts has received only limited study (Connor and McMillan 1988, Santillo 1994), and only Raymond et al. (1996) have examined habitat use (i.e. browse use) >3 years after treatment. Our objectives were to determine effects of treating regenerating clearcuts with glyphosate on (1) use of clearcuts by moose and (2) conifer cover during 2 periods, 1-2 and 7-11 years posttreatment.

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METHODS

Study Area and Design

We conducted the study in the vicinity of Moosehead Lake in northern Somerset and Piscataquis counties, Maine. Forests in the region are classified as spruce *(Picea* spp.)-balsam fir *(Abies* foa/samea)-northern hardwoods (Westvald et al. 1956) and were primarily managed for timber production. Regeneration on clearcuts was dominated by paper birch *(Betula papyrifera),* pin cherry (Primus *pensylvanica),* red maple *(Acer rubrum),* aspen spp. *(Populus tremuloides* or *P. grandidentata),* balsam fir, and spruce spp. Striped maple (A. *pensylvanicum),* white pine *(Pinus strobus),* northern white cedar *(Thuja occidentalis),* mountain maple (A. *spicatum),* sugar maple (A. *saccharum),* yellow birch (B. *alleghaniensis),* mountain ash *(Sorbus americana],* and willow *(Salix* spp.) were common. Plant nomenclature follows McMahon et al. (1990). Moose were abundant and estimated population density was 1.2-1.8 per km^2 in the region (Maine Dep. Inland Fish, and Wildl., unpubl. data).

We selected 12 clearcuts to study effects of glyphosate at 1-2 years posttreatment. Clearcuts were 18-89 ha in area, dominated by deciduous tree regeneration (1-3 m tall), had tall (>12 m) conifer or mixed conifer-deciduous forest around at least 75% of their perimeters, and were clearcut harvested 4.5-8.5 years before the treatment year. We measured habitat use and coniferous vegetation on all 12 clearcuts during January-March 1991 before glyphosate treatment of 6 clearcuts in August 1991. We conducted posttreatment sampling during January-March 1992 and 1993. We paired clearcuts according to vegetation, age, and location to reduce variation between treatment and control clearcuts, and we randomly assigned 1 clearcut from each pair to receive a single application of glyphosate (1.65 kg acid equivalents/ha). Sites were treated by helicopter by Scott Paper Co.

We selected 11 clearcuts, each 21-73 ha, to study effects of glyphosate at 7-11 years posttreatment. All clearcuts had tall conifer or mixed conifer-deciduous forest around at least 75% of their perimeters. Six clearcuts had received a single aerial application (1.65 kg acid equivalents/ha) of glyphosate 6.5-9.5 years before initial sampling (1992). Five clearcuts had not been treated. Average age since harvest was 19 years for untreated clearcuts and 16 years for treated clearcuts. Additional information on clearcuts can be found in Raymond et al. (1996). We measured habitat use by moose on the 6 previously-treated clearcuts and 5 untreated clearcuts in January-March 1992 and 1993 and measured coniferous vegetation in 1992 or 1993.

Habitat Use and Conifer Cover

To determine if moose use of treated and untreated clearcuts was similar before treatment, we made aerial counts of moose track aggregates (McNicol and Gilbert 1980, Connor and McMillan 1988) in January-March 1991 on the 12 clearcuts used to study 1-2-year effects. We mapped track patterns on each clearcut, and we defined a track aggregate as a distinct group of tracks from > 1 moose that had entered and/ or exited a clearcut (McNicol and Gilbert 1980). Ground surveys conducted the day after a subset of aerial surveys confirmed that tracks were highly visible from the air (W. E. Eschholz, unpubl. data). We conducted 6 surveys on each of the 12 clearcuts from a fixed-wing aircraft 3-5 days after snowfalls of > 10 cm (LaResche and Rausch 1974). For each survey, counts were made on all clearcuts on the same day. We expressed data as track aggregates per hectare of clearcut and assumed any bias in our method was equivalent between treatment and control clearcuts because vegetative characteristics were similar (Raymond et al. 1996).

In January-March 1992 and 1993, we made ground counts of track crossings (tracks), beds, and pellet groups on permanent 2-m-wide transects on all 23 clearcuts. We located transects along the entire perimeter of each clearcut. We also located additional parallel transects in the interior of larger clearcuts to provide equal transect density (75 m/ha) on all clearcuts. We conducted counts 3-7 days *(x* = 4) after each snowfall > 10 cm. We backtracked all track crossings for 20 m and classified moose activity for each track crossing as foraging if there was >1 instance of browsing activity. We expressed all data as counts/km of transect. We conducted counts 6-7 times on all clearcuts in January-March 1992 and 5 times in January-March 1993. Mean monthly (Jan-Mar) snowdepths on sites with no tree canopy in the region were 42-62, 19-48, and 19-73 cm in 1991, 1992, and 1993

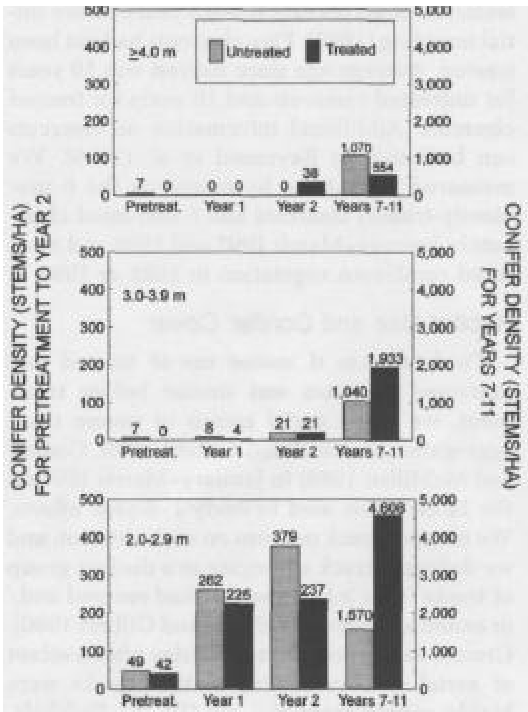

Fig. 1. Densities (/ha) of conifer tree stems by height class for glyphosate-treated and untreated clearcuts at pretreatment and 1, 2, and 7-11 years posttreatment in Maine, January-March 1991-93. Clearcuts used to study 1 -2 year effects were treated in August 1991 after pretreatment sampling in January-March 1991.

(Maine Dep. Inland Fish., and Wildl., unpubl. data), and did not appear to affect use of clearcuts by moose except in March 1993. We suspended counts in mid-March 1993 because snow depths reached 90 cm and may have restricted movements by moose (Coady 1974).

We counted live stems of conifers by height class (2.0-2.9, 3.0-3.9, and >4.0 m) on 2- x 5-m quadrats randomly located on transects distributed systematically on each clearcut. We sampled 24 quadrats per clearcut in 1991 and 40 quadrats per clearcut in 1992 and 1993.

Statistical Analyses

We used a paired t-test to test for pretreatment differences in aerial counts of track aggregates between clearcuts designated for glyphosate treatment and control clearcuts. We analyzed track, bed, and pellet group counts from ground transects and conifer data using analysis of variance (ANOVA) on ranks because data were not normally distributed (Zar 1984:176). For tests of 1-2-year effects on conifer density, repeated-measures ANOVA was used. In these analyses, year x treatment interactions were considered evidence of treatment effects because the study design included pretreatment data. 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 when it is false).

RESULTS

1-2-Year Effects.—Conifer densities in height strata >2 m were relatively low on treated and untreated sites compared to older clearcuts, and treatment did not affect $(P > 0.10)$ density of conifer stems at any height class (Fig. 1). In the pretreatment year (1991), aerial counts of moose track aggregates (counts/ha) did not differ $(P = 0.69)$ between clearcuts designated for treatment $(x \pm SE = 0.07 \pm 0.02)$ and control $(x \pm SE = 0.08 \pm 0.01)$ clearcuts. Posttreatment counts of tracks of foraging moose on treated clearcuts were less $(P = 0.013)$ than counts on untreated clearcuts (Fig. 2). Mean values were 57 and 75% lower on treated than untreated clearcuts in years 1 and 2, respectively. Counts of beds $(P = 0.10)$, total (all moose) tracks $(P = 0.14)$, and pellet groups $(P = 0.12)$ did not differ between treated and untreated clearcuts, but means paralleled the negative effect observed for tracks of foraging moose. Counts of total tracks were greater $(P < 0.10)$ in 1993 than 1992. There were no treatment x year interactions for track, bed, or pellet group counts $(P = 0.42\text{-}0.90)$.

7-11-Year Effects.-Density of conifer stems 2.0-2.9 m tall was about 3 times greater $(P < 0.10)$ on treated than untreated clearcuts, but densities did not differ for other height classes $(P > 0.10)$ (Fig 1.). Counts of tracks of foraging moose $(P = 0.05)$ and beds $(P = 0.06)$ were greater on treated than untreated clearcuts (Fig. 2). Treatment did not affect counts of total tracks $(P = 0.19)$, and pellet groups $(P = 0.17)$, but means paralleled positive effects observed for tracks of foraging moose and beds on treated clearcuts. There were no treatment x year interactions for track, bed or pellet group counts $(P = 0.28\text{-}0.95)$.

DISCUSSION

Glyphosate treatment appeared to improve cover for bedding on regenerating clearcuts by 7-11 years posttreatment. McNicol and Gilbert (1978) found that 80% of moose beds in 10-15-year-old clearcuts in winter were associated with

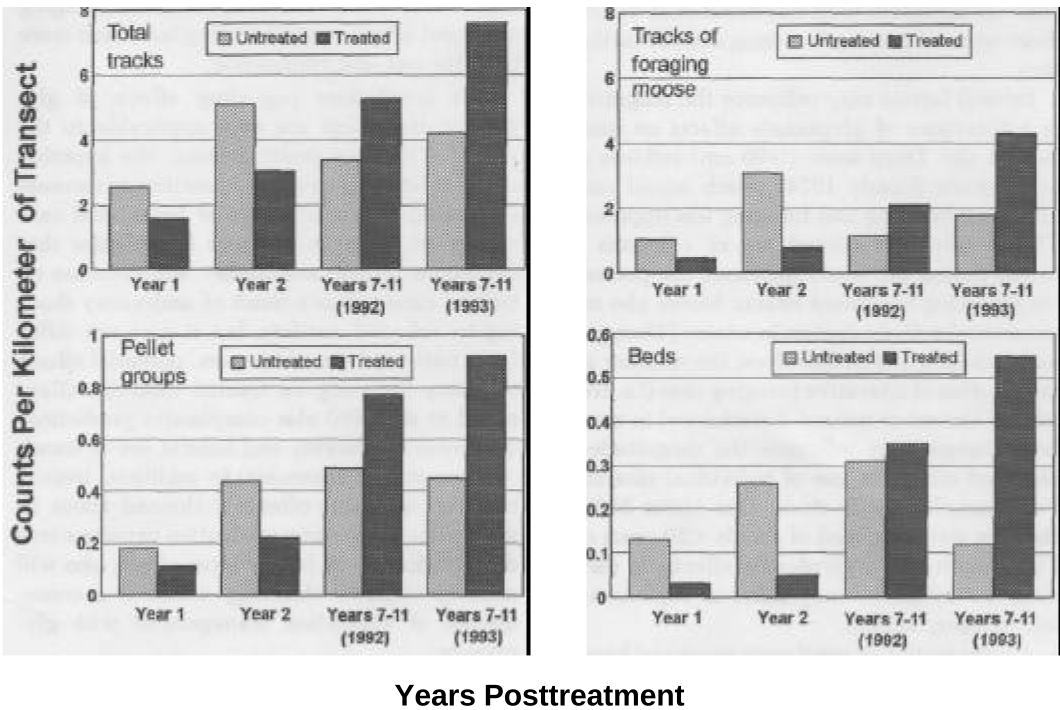

Fig. 2. Counts (per km of transect) of moose track crossings, beds, and pellet groups on glyphosate-treated and untreated clearcuts 1, 2, 7-11 years posttreatment in Maine, January-March 1992-93. Clearcuts used to study 1-2-year effects were treated in August 1991.

immature (2.5-7.6-cm dbh) conifer clumps, and beds were positioned to take advantage of wind-breaking cover and exposure to the sun. Densities of conifer trees of approximately this size (2.0-2.9 m in height) were substantially greater on treated than untreated sites during years 7-11, and we observed greater counts of beds on these clearcuts. Trees on older treated clearcuts also appeared to have more canopy cover than conifers on untreated sites because released conifers were less influenced by competition from tall deciduous tree cover (Newton et al. 1992). In contrast, young clearcuts (treated and untreated) provide little winter cover because conifer trees were small and deciduous trees (live and/or dead stems) dominated sites.

Comparable data on bedding rates in clearcuts and unharvested stands are not available, and previous studies on habitat use in harvested forests were conducted before extensive herbicide use (Phillips et al. 1973, Thompson and Vukelich 1981, Monthey 1984). We did not measure bedding rates in adjacent unharvested stands, but our anecdotal observations indicated that bedding rates in older treated clearcuts were substantial. We saw no evidence that moose activity in clearcuts was affected by snow depth during the 3 years of our study except late March 1993.

Glyphosate treatment reduces, but does not eliminate, use of clearcuts by moose in the first 1-2 years after treatment. Connor and McMillan (1988) found a decrease (48%) in track counts from aerial surveys during the third winter posttreatment similar to the 57-75% reduction in tracks of foraging moose we observed during years 1-2. We did not detect a statistical difference on total track counts in years 1-2, but the trend was similar to the negative treatment effect we observed for counts of tracks of foraging moose suggesting that moose activity was reduced overall. The fact that young treated and untreated clearcuts appear vegetatively similar in winter (i.e., dead stems are still standing and are similar in appearance to live stems) probably accounts for some moose activity in treated clearcuts. In contrast to negative effects on habitat use in years 1-2, older treated clearcuts were used more than younger treated sites or untreated sites overall. High use of older treated clearcuts was consistent with Raymond et al.'s (1996) observation of greatest browsing activity on these sites.

Several factors may influence the magnitude or importance of glyphosate effects on moose habitat use. Deep snow (>90 cm) reduces use of clearcuts (Coady 1974) which would make effects on bedding and foraging less important. The largely unrestricted use of clearcuts by moose during our study increased the potential for observing treatment effects. Moose also may use several activity centers in winter (Thompson and Vukelich 1981); therefore, the number and distribution of alterative foraging sites (i.e. from timber harvest or natural disturbance) in winter home ranges may influence the magnitude of observed effects on use of individual clearcuts. For example, in our study area about 50% of the area was composed of stands <20 years old. The magnitude of glyphosate effects on use of clearcuts by moose may differ in regions with less foraging habitat.

A combination of coniferous cover and browse availability appears to explain the pattern of habitat use we observed after treatment. Raymond et al. (1996) found a 70% decrease in available deciduous browse from pretreatment to year 2 on these clearcuts and found little evidence that there were important effects on the nutritional quality of available browse or diet quality of moose. With dead deciduous stems largely still standing and conifer height little changed, physical cover is unaffected by treatment in the first few years, and, therefore, the decrease in track counts appears to be the result of decreased browse availability. At 7-11 years posttreatment, greater counts of beds and tracks of foraging moose (this study) and browse use (Raymond et al. 1996) on treated sites appeared to be the result of more abundant tall conifer cover because browse availability was similar for treated and untreated clearcuts at 7-11 years and was similar to treated sites at year 2 (Raymond et al. 1996). We hypothesize that moose made greater use of older treated clearcuts for foraging because they can bed and forage in the same area. The high percentage of browse use observed on older treated clearcuts also suggest intensive use. Risenhoover (1986) reported that moose fed 5-6 times per day in winter, feeding periods averaged about 1 hour each, and moose alternated between resting and feeding during the entire day. High interspersion of bedding cover and browse on treated clearcuts may reduce travel to and from bedding and foraging areas and allow shorter foraging bouts and more time for rest and rumination.

Our conclusions regarding effects of glyphosate treatment are only applicable to the period <11 years posttreatment. We hypothesize that bedding cover will continue to increase on treated clearcuts as conifer height and canopy cover increase. We also hypothesize that deciduous browse availability will decrease on treated clearcuts as a result of understory shading by released conifers, but it may not differ from untreated sites. However, potential effects of heavy browsing on treated clearcuts (Raymond et al. 1996) also complicates predictions of browse availability and habitat use of stands >11 years posttreatment. In addition, treated clearcuts in Maine often are thinned about 10 years after glyphosate application to reduce tree density. Studies of longer-term effects also will need to evaluate thinning, which is a consequence of vegetation management with glyphosate.

MANAGEMENT IMPLICATIONS

If greater use of treated clearcuts by moose at 7-11 years after treatment is an indication that habitat quality increases as treated sites developed vegetatively, then benefits of improved habitat at approximately 7-11 years after treatment may partially offset negative effects on browse availability and habitat use the first few years after treatment. However, whether moose using older treated clearcuts have an energetic advantage over moose using untreated sites is unknown. Despite this uncertainty, we recommend timber harvest and treatment strategies that result in pretreatment and 7-11 year posttreatment forest stands in proximity to recently treated stands as a conservative approach to stabilizing overall habitat quality for moose. Effects on other wildlife will be species-specific (Lautenschlager 1993), but the above management strategy for moose is consistent with general recommendations for maintaining songbird diversity in areas receiving herbicide treatment (Santillo et al. 1989).

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