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Effect of vegetation management for reducing damage to lodgepole pine seedlings from northern pocket gophers

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The effects of vegetation management on northern pocket gopher (*Thomomys talpoides*) activity and damage to lodgepole pine (*Pinus contorta*) seedlings were studied using 2,4-D herbicide to alter the habitat. Treatments were applied to a large (8.1 ha) treatment unit and observed effects were compared with an untreated control unit of the same size. The greatly reduced forb and grass cover on the treated unit was associated with a corresponding decrease in pocket gopher activity that persisted for 6 years after initial treatment. Times until seedlings first incurred gopher damage and overall survival of seedlings were greatly increased on the treated unit. Published by Elsevier Science Ltd

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Pocket gophers (*Thomomys* spp.), through severing or girdling of stems and roots, cause considerable damage to reforestation efforts in the Pacific Northwest (e.g. Barnes, 1973; Crouch, 1986), and may account for more damage to natural or artificially planted conifers in western forests than all other animals combined (Crouch, 1986). The successional vegetation that follows timber cutting or forest fire improves gopher habitat; reforestation problems are largely a result of gopher populations responding to favorable changes in their habitat (Barnes, 1973). Planting or seeding usually takes place soon after the forest canopy has been removed, resulting in seedlings being most vulnerable when the habitat is optimal for gophers and their densities are greatest. Natural successional processes are slow and tree stocks often do not survive long enough to be protected by brush establishment, which sometimes results in lower forb cover, and consequently in lower pocket gopher density (Barnes, 1974).

Damage reduction has usually involved reducing pocket gopher populations directly through the use of trapping or toxicants (e.g. Crouch and Franks, 1979). However, the habitat still remains favorable for pocket gopher occupancy after their populations are reduced. Pocket gopher populations often recover rapidly (Campbell *et al.*, 1992). Thus, toxicants often produce only short-term control (Sullivan, 1986). Regular lethal treatments are needed to provide adequate population suppression until the seedlings have grown beyond a vulnerable size.

Manipulation of habitat characteristics relating to food and cover can have a substantial effect on rodent populations (Hansson, 1975). Vegetation management through the use of herbicides on rangelands has resulted in reductions in pocket gopher populations (Hull, 1971; Keith *et al.*, 1959; Tietjen *et al.*, 1967). Others have described improved seedling establishment environments and increased seedling stocking rates following the use of herbicides (Cristensen *et al.*, 1974; Crouch, 1979; Crouch and Hafenstein, 1977). Manipulations of vegetation have produced reductions in pocket gopher populations and corresponding reductions in damage in orchards (Sullivan and Hogue, 1987). Black and Hooven (1977) demonstrated improved seedling survival for five species of conifer from the use of combinations of herbicides including atrazine, simazine and 2,4-D. Recently, substantially improved survival of ponderosa pine seedlings (*Pinus ponderosa*) and long-term reductions in Mazama pocket gopher (*Thomomys mazama*) populations were demonstrated following atrazine treatments (Engeman, Barnes, Anthony and Krupa, 1995a). In addition to the potential for sustained efficacy, vegetation management is an appealing control method because of increasing interest in the use of non-lethal means to reduce animal damage (Acord, 1992; Engeman *et al.*, 1995b).

This paper presents unique long-term data following 2,4-D herbicide treatment where the indivi-

[§]To whom correspondence should be addressed dual fates of a large number of lodgepole pine (*Pinus contorta*) seedlings were regularly monitored for 4 years while measurements were simultaneously made on northern pocket gopher (*Thomomys talpoides*) activity and the effects of herbicide treatment on the vegetation.

Materials and methods

The study was conducted on the site of the 1930 Dugout Lake forest fire in the Sisters Ranger District of the Deschutes National Forest, Oregon. This 433 ha burn had been planted or seeded with ponderosa pine in 1963, 1964 and 1969, but by 1972 the plantings had failed, primarily owing to gopher damage (Barnes, 1974). The vegetation on the study site was primarily a lodgepole pine–lupin (*Lupinus argenteus*)–penstemon (*Penstemon euglaucus*) plant community (Volland, 1976). This flat to gently rolling area (slopes 0–15%) at an elevation of 1500 m was covered with pumice soils. The pocket gopher found in this area was the northern pocket gopher.

Within this area, two 8.1 ha units were selected to study the effect of herbicidal manipulation of vegetation on associated northern pocket gopher populations, and their damage to lodgepole pine seedlings. The vegetation on one of the units was managed by herbicide treatment with 2,4-D, and the other unit served as an untreated control. The units were separated by a minimum buffer of approximately 400 m. Use of study units of this size permitted assessment of responses by populations of gophers to the treatment and provided an evaluation of the resulting effects on seedlings in an operational context. Experimental logistics and resources precluded replication using other pairs of large units.

Gopher activity was measured on each unit using 100 circular activity plots of 81 m^2. Forty-eight hours after erasing all gopher sign in each plot, mounds and plugged burrows were used to provide a present–absent assessment of activity (Anthony and Barnes, 1984). Activity plots on the treated unit were located along 25 randomly placed lines of four plots with 18–20 m separating the center points of the plots. Activity plots on the control unit were similarly placed, but with five plots along each line. Activity assessments were made each September from 1971 to 1978.

Vegetation cover measurements were taken in each plot on both units using the Daubenmire technique (Daubenmire, 1959) to demonstrate treatment efficacy on the plant community. This involved using a 20 m × 50 cm rectangular plot, randomly located 1 m from the center post in each activity plot. Percentage canopy-cover measurements were made within each plot for grasses, forbs, and shrubs. Data were collected each August from 1970 to 1977. Each year, goodness-of-fit tests were applied to compare canopy-coverage of each vegetation category between the treated and control units.

Herbicide was applied in June 1972 and June 1973 at a rate of 2.3 kg acid equivalent in 187.5 l water carrier ha^{-1} using boom rigs attached to a tractor. Spot treatment using backpack apparatus was applied in June 1974 primarily to control lupin. At the end of October 1974, the burn area, including the study units, was operationally auger-planted at approximately 1000 trees ha^{-1} with lodgepole pine seedlings that were nursery-grown for 2 years. Within each unit, 20 lines of ten seedlings were randomly selected for monitoring gopher damage and survival. Each of these seedlings were observed while alive twice each growing season (spring, autumn) from 1975 to 1977 and in the spring of 1978.

The percentage of activity plots that were observed with gopher activity was compared between the treated and control units each year by applying Pearson's χ^2 test to 2 × 2 contingency table data. Times until first gopher damage and seedling survival time were nonparametrically analyzed using Kaplan and Meier (1958) survival analyses. Wilcoxon comparisons of the resulting survival curves (Kalbfleish and Prentice, 1980) were used to test whether differences in damage or survival rates occurred during the time course of the study between the seedlings on the treated unit and the seedlings on the control unit.

Results

The vegetation cover measurements (*Table 1*) verified the efficacy of the 2,4-D treatments. Before treatment, no differences in forb canopy-coverage were detected between treated and control units ($P > 0.35$ each year). After 1972, the forb canopy-coverage was drastically reduced on the treated unit relative to the control unit ($P < 0.01$ each year). Thus, an effective test of vegetative manipulation was produced between the treatment and control units. Even 3 years after the final (maintenance) treatment, forb

Table 1. Percent canopy cover for forbs and grasses on the treated and control units measured each August from 1970 to 1977,[a] where 2,4-D herbicide was applied to the treated unit in June of 1972, 1973 and 1974

	Forbs				Grasses			
Year[a]	Treated	Control	χ^2 (1 d.f.)	P	Treated	Control	χ^2 (1 d.f.)	P
1970	11.51	13.10	0.102	0.75	19.62	14.00	0.939	0.33
1971	10.10	9.45	0.022	0.88	26.40	19.98	0.889	0.35
1972	7.83	11.99	0.873	0.35	22.80	21.69	0.028	0.87
1974	3.03	14.30	7.329	0.01	43.55	35.45	0.831	0.36
1975	1.55	9.79	5.987	0.01	38.30	27.58	1.744	0.19
1976	2.85	13.10	6.587	0.01	42.70	35.30	0.702	0.40
1977	2.48	10.30	4.785	0.03	38.60	27.00	2.051	0.15

[a]Data from 1973 were lost in a laboratory fire

cover on the treated unit was only a fraction of that on the control unit (*Table 1*). In 1972, the year 2,4-D was first applied, the treatment and control units had nearly the same canopy-coverage by grasses (*Table 1*). By the end of the study, grass canopy-coverage on the treated unit had increased by nearly 50% from the 1972 level, whereas it only increased by about 25% on the control unit. However, in no year was a significant difference in grass canopy-coverage detected ($P > 0.15$ each year). Shrubs made up less than one-quarter of 1% of the canopy-coverage each year on both units and, therefore, probably did not play an important role in influencing gopher activity.

No differences were detected in gopher activity between the treated and control units in 1971, before the first herbicide treatment ($\chi^2 = 0.347$, d.f. = 1, $P = 0.556$). Similarly, no differences in activity were detected in 1972, the same summer as the first treatment application ($\chi^2 = 0.739$, d.f. = 1, $P = 0.390$). However, in each subsequent year (to 1978), the percentage of active plots on the treatment unit was substantially less ($P \leq 0.001$ for each year) than on the control unit (*Table 2*).

The proportions of seedlings attacked by gophers at each observation time were substantially less on the treated unit (*Table 3*), resulting in significant differences between seedling survival curves (Wilcoxon comparison of Kaplan–Meier survival curves; $\chi^2 = 78.69$, d.f. = 1, $P < 0.0001$). The mean time until first gopher damage among the control unit seedlings was 530 days (SE = 30 days) vs 946 days (SE = 33 days) for the seedlings on the treated unit.

The overall survival of seedlings was substantially greater for seedlings on the treated unit (Wilcoxon comparison of survival curves; $\chi^2 = 72.69$, d.f. = 1, $P < 0.0001$). In the analyses of time until first gopher damage, seedlings dying from causes other than gopher damage (such as weather or unknown causes) were considered withdrawn from the study at the point of death, whereas, in examining survival, death from all causes was used as an endpoint for analysis. Therefore, mean survival times are slightly less than the mean times until gopher damage, but show the same trends. The control unit seedlings had a mean survival time of 522 days (SE = 29 days) vs 896 days (SE = 33 days) for the seedlings on the treated unit.

Table 2. Percent of gopher activity plots with fresh sign (within 48 h) on the treated and control units; 1972 was the initial 2,4-D treatment year

Year[a]	Treated % Active	Control % Active	χ^2 (1 d.f.)	P
1971	38	34	0.347	0.556
1972	39	45	0.739	0.390
1974	33	69	25.930	<0.001
1975	33	71	28.926	0.001
1976	27	79	54.275	<0.001
1977	17	66	49.449	<0.001
1978	20	69	48.608	<0.001

[a]Data from 1973 were lost in a laboratory fire

Discussion

This study suggests that a reduction in gopher activity and an increase in survivorship of lodgepole pine seedlings can be achieved by 2,4-D treatments after clearing. Although the proximity, similarity, and pretreatment vegetation and activity assessments provided reasonable assurances that differences in response between our two units would be due to treatment effects, confirmation with additional units would be highly desirable to provide more general inferences.

Burton and Black (1978) described aboveground parts of forbs as forming the largest component in the diet of Mazama pocket gophers. Succulent forbs were preferred to all other plants. Our treatments produced an altered habitat where most of these important dietary elements were greatly diminished, so it should not be surprising that gopher activity was greatly reduced on the treatment unit. If the decrease in forbs is accompanied by an increase in grass cover, then the recovery of the forbs, and hence the pocket gophers, might be further delayed. The results presented here using 2,4-D to protect lodgepole pine seedlings from northern pocket gophers were similar to those achieved by Engeman *et al.* (1995a) in a different habitat for protecting ponderosa pine seedlings from Mazama pocket gophers. Lack of important food sources on the treatment areas in that study and the present one appeared to inhibit reinvasion of both species of pocket gopher. It is especially noteworthy that the activity (and damage) remained suppressed at least 6 years beyond the initial treatment. Given the increase in grasses on our treated unit, it might be useful to examine the potential of combining herbicide treatment with the planting of less-preferred pocket gopher vegetation for further long-term suppression of pocket gopher populations.

Another question to examine when using any nonlethal control method to avert animal damage in an area is whether the production of an undesirable habitat increases the pressure on nearby areas that have not been treated. We presume that a partially herbicide-treated clearcut would have increased gopher populations in the untreated portions. However, a completely treated clearcut surrounded by a buffer of forest, which also is less desirable

Table 3. Percent ($n = 200$ seedlings per unit) of seedlings planted in 1974 not damaged by gophers on a 2,4-D herbicide treated unit and an untreated control unit

	Months after planting						
TQc	7	11	20	23	31	36	44
Treated unit	81.0	77.5	64.1	63.5	57.9	57.4	51.4
Control unit	46.5	43.5	25.1	24.0	17.5	16.4	9.1

gopher habitat, would probably create little gopher pressure on other clearcuts unless the forest buffer was very narrow.

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