BUTTERWORTH HEINEMANN

0261-2194(95)00034-8

Crop Protection Vol. 14, No. 6, pp. 505-508, 1995
Elsevier Science Ltd
Printed in Great Britain

Vegetation management for reducing mortality of ponderosa pine seedlings from *Thomomys* spp.

Richard M. Engeman,[*] Victor G. Barnes, Jr.,[†] Richard M. Anthony[‡] and Heather W. Krupa[*]

[*]USDA/APHIS, Denver Wildlife Research Center, P.O. Box 25266, Bldg. 16, Denver Federal Center, Denver, CO 80225-0266, USA, [†]USDI/NBS, Kodiak National Wildlife Refuge, 1390 Buskin River Rd., Kodiak, AK 99615, USA, and [‡]USDI/NBS, Alaska Fish and Wildlife Research Center, 1011 E. Tudor Rd., Anchorage, AK 99503, USA

The effects of vegetation management on Mazama pocket gopher activity and damage to ponderosa pine seedlings were studied using atrazine herbicide to alter the habitat. Atrazine treatments were applied to a large treatment unit and observed effects were compared to an untreated control unit. The greatly reduced forb and grass cover on the treated unit was associated with a corresponding decrease in pocket gopher activity. Times until seedlings first incurred gopher damage and overall survival of two cohorts of seedlings were greatly increased on the treated unit.

Keywords: vegetation management, animal damage, reforestation, survival analysis, pocket gopher

Pocket gophers (*Thomomys spp.*) are responsible for considerable damage to reforestation efforts in the Pacific Northwest (e.g. Barnes, 1973). These reforestation problems are largely a result of the animals responding to changes in their habitat (Barnes, 1973). Forest pocket gophers tend to be broadly dispersed throughout stands of timber, but concentrated in mesic sites at breaks in the forest canopy where the growth of ground vegetation provides ample forage. The successional vegetation that follows timber cutting or fire improves gopher habitat. Planting or seeding usually takes place soon after the forest has been opened, resulting in seedlings being most vulnerable when the habitat is optimal for gophers and their densities are greatest. Sometimes brush establishment results in lower forb and grass cover, and consequently in lower pocket gopher density (Barnes, 1974). However, natural successional processes are slow and tree stocks often do not survive long enough for this form of protection to occur.

Damage reduction has usually involved managing the pocket gopher populations directly through the use of trapping or rodenticides. After the pocket gopher populations are reduced, the habitat remains favorable for their occupancy and often is rapidly repopulated (Campbell *et al.*, 1992). Thus, regular lethal treatments are needed to provide adequate population suppression until the seedlings have grown beyond a vulnerable size. In addition, there is an increasing interest in the use of non-lethal means to reduce animal damage (Acord, 1992). Here we are interested in reducing pocket gopher populations through altering their habitat with the use of herbicides.

Little recent literature is available on the use of herbicides to manage pocket gopher populations by managing their habitat. Past studies have demonstrated immediate reductions in pocket gopher food resources through herbicide treatments with an associated decline in pocket gopher population indices. Keith, Hansen and Ward (1959) demonstrated that 2,4-D applications in Colorado rangeland habitat resulted in a virtual elimination of forbs, followed by a reduction in gopher numbers in succeeding years. Hull (1971) reported reduced pocket gopher abundance in Idaho rangelands after 2,4-treatment. Other studies have reported increased seedling stocking rates following herbicide treatment. Cristensen, Young and Evans (1974) described a reduction in competing plants through atrazine treatments that resulted in improved stocking rates of ponderosa pine seedlings. Similarly, Crouch and Hafenstein (1977) described an enhanced seedling-establishment environment through atrazine treatment and an associated improvement in ponderosa pine seedling stocking rates. They hypothesized that the improvement in stocking rate also may have been due to an associated reduction in pocket gopher populations. Crouch (1979) further described improved long-term seedling survival rates and diminished gopher activity on the series of 0.04 ha plots that received atrazine treatments. Black and Hooven (1977), using three herbicide treatments, demonstrated much improved seedling survival for five species of conifer from the use of combinations of herbicides including atrazine, simazine and 2,4-D.

This paper presents results from a study that monitored the effects over time of herbicide treatment on pocket gopher activity, and the individual fates of a large number of seedlings, thus providing comparisons of survival curves between treated and control areas.

Materials and methods

The study was conducted on the site of the 1959 Cave Mountain wildfire in the Chiloquin Ranger District of the Winema National Forest, Oregon. Parts of this 6000 ha burn were planted or seeded with ponderosa pine (*Pinus ponderosa*) in 1961–1963, but by 1965 the plantings had failed, primarily due to gopher damage (Barnes, 1973). The vegetation on the study site was primarily a ponderosa pine – bitterbrush (*Purshia tridentata*) – needlegrass plant (*Stipa occidentalis*) community (Volland, 1976) with primary forbs such as spreading groundsmoke (*Gayophytum diffusum*), annual willow-herb (*Epilobium paniculatum*), Douglas's knotweed (*Polygonum douglasii*), and mullein (*Verbascum thapsus*), grasses dominated by needlegrass, squirrel tail (*Sitanion hystrix*), mountain brome (*Bromus carinatus*), and cheatgrass (*B. tectorum*), and primary, but widely scattered shrubs, such as ceanothus (*Ceanothus velutinus*), manzanita (*Arctostaphylos patula*), bitterbrush and rabbitbrush (*Chrysothamus* spp.). Mature ponderosa pine and aspen (*Populus tremuloides*) were dispersed throughout the area. This gently rolling area (slopes 0–15%), with elevations from 1340 to 1525 m, was covered with pumice soils up to 1.5 m deep. The pocket gopher found in this area was the Mazama pocket gopher (*Thomomys mazama*).

Within this area, two units of 4.9 ha each were selected to study the effect of herbicidal manipulation of vegetation on associated pocket gopher populations, and their damage to ponderosa pine seedlings. One of the units was randomly selected to have its vegetation managed by herbicide treatment with atrazine (reference to trade names does not imply endorsement of commercial products by the federal government) and the other unit served as an untreated control. The units were separated by a minimum buffer of 40 m. Use of study units nearly 5 ha in size permitted reliable assessment of responses by populations of gophers to the treatment and provided a realistic evaluation of the resulting effects on seedlings in an operational context. Experimental logistics and resources did not allow for replication using other pairs of sites. Although the proximity, similarity and pre-treatment vegetation and activity assessments provided reasonable assurances that differences in response between these two units would be due to treatment effects, confirmation with additional units would be highly desirable to provide more general inferences.

In order to measure gopher activity and vegetation cover, five randomly placed lines of 10 'activity' posts, spaced at 20 m intervals, were defined on each unit. At each post, gopher activity was measured in an 81 m^2 circular plot where mound counts and plugged burrows (Anthony and Barnes, 1984) were used to provide a yes–no assessment 48 hr after all gopher sign in each plot had been erased. Activity assessments were made each August from 1974 until 1979. Vegetation cover measurements were taken in each plot on both units to demonstrate treatment efficacy on the plant community. A rectangular plot, 20 × 50 cm, was randomly located 1 m from the center post in each activity plot. Percentage canopy cover measurements for grasses, forbs and shrubs were made using the Daubenmire technique (Daubenmire, 1959). Phenological measurement of treatment effects on the plant community during the short growing season was obtained from 1974 until 1979 by sampling vegetation at emergence (June, referenced as early measurements) and at peak vegetation (July, referenced as late measurements).

The herbicide was initially applied (formulated as 3.4 kg of 80% active ingredient atrazine per 76 l of water) in November 1974. Nearly 2 years were allowed to elapse before planting with 2–0 ponderosa pine seedlings to permit the spray to have an effect on the vegetation in the treated unit. In March of 1976 the burn area, including the study units, was operationally planted at a rate of approximately 280 trees/ha. A second atrazine spray (2.55 kg of 80% active ingredient atrazine per 76 l of water) was spot applied to the treated unit in November 1977 as a maintenance measure and was followed by a second planting of seedlings in April of 1978 on only the study unit (not on an operational basis) to provide two cohorts of seedlings for study. Only 1 year was allowed to pass between the second spraying and the second planting because vegetation was already suppressed at the time of the spray.

Within each unit, 20 lines of 10 seedlings from the first planting were randomly selected for monitoring gopher damage and survival. Another set of 20 lines of 10 seedlings each was established in each plot using seedlings from the 1978 planting. All seedlings were observed 2–4 times each growing season until 1979 for first gopher damage and survival.

Activity measurements were compared between the treated and control units each year by applying Pearson's χ^2 to 2 × 2 contingency table data. Times until first gopher damage and survival time were analyzed nonparametrically using Kaplan–Meier (1959) survival analyses.

Results

The vegetation cover measurements (*Table 1*) verified the efficacy of the atrazine treatments. The forbs and grasses were drastically reduced, thus producing an effective test of vegetative manipulation on the treatment unit. Shrubs were not very abundant to begin with and therefore probably did not play an important role in reducing gopher activity. Even 3 years after the final (maintenance) treatment, forb and grass cover on the treated unit was only a fraction of that on the control unit (*Table 1*).

A comparison of gopher activity between the treated and control units in 1974, before treatment, detected no differences ($\chi^2 = 0.585$, df $= 1$, $p = 0.444$). However, in each subsequent year (until 1979), the percentage of plots active in the treatment unit was substantially less ($p \leq 0.001$ for each year) than on the control unit (*Table 2*).

The rates at which seedlings were attacked by gophers were greatly decreased on the treated unit for

Table 1. Per cent canopy cover for forbs, grasses, and shrubs on the treated and control units from 1974 until 1979, where the 1974 measurements are pre-treatment and the 1975–1979 measurements are post-treatment

Year	Time	Forbs Treated	Forbs Control	Grasses Treated	Grasses Control	Shrubs Treated	Shrubs Control
1974	Early	31.00	24.30	14.30	11.30	0.00	0.35
	Late	35.30	22.60	13.10	8.85	0.00	0.05
1975	Early	0.45	21.90	1.25	8.80	0.00	0.30
	Late	0.25	24.80	1.25	7.40	0.00	0.35
1976	Early	2.35	14.70	1.50	7.20	0.00	0.05
	Late	5.15	31.00	0.65	8.60	0.00	0.30
1977	Early	4.55	5.80	0.20	9.65	0.05	0.10
	Late	11.70	21.70	0.15	10.70	0.05	0.10
1978	Early	1.55	27.20	0.15	12.80	0.00	0.35
	Late	4.00	34.70	0.10	14.10	0.00	0.30
1979	Early	5.80	17.90	0.60	13.00	0.15	0.35
	Late	9.90	18.80	0.25	18.10	0.05	1.10

Table 2. Per cent of gopher activity plots with fresh sign (within 48 hr) on the treated and control units, where the 1974 measurements are pre-treatment and the 1975–1979 measurements are post-treatment

Year	Control % active	Treated % active	χ^2 (1 df)	p
1974	78	84	0.585	0.444
1975	76	10	44.431	<0.001
1976	82	16	43.577	<0.001
1977	48	18	10.176	0.001
1978	72	8	42.667	<0.001
1979	52	4	28.511	<0.001

both cohorts (*Table 3*), resulting in significant differences between survival curves (Wilcoxon comparison of Kaplan–Meier survival curves $\chi^2 = 149.42$, df = 1, $p < 0.0001$ for 1976 cohort; $\chi^2 = 89.13$, df = 1, $p < 0.0001$ for 1978 cohort). The mean time until first gopher damage for the 1976 cohort was 443 days (s.e. = 26 days) for the control unit vs 1156 days (s.e. = 33 days) for the treated unit. For the 1978 cohort, which did not have the benefit of a maintenance spray 1 year after planting, the mean time until first gopher damage was 433 days (s.e. = 22 days) for the control unit and 733 days (s.e. = 13 days) for the treated unit.

The overall survival of seedlings also was substantially greater for both cohorts of seedlings on the treated unit, and also resulted in significantly different survival curves (Wilcoxon comparison of survival curves; $\chi^2 = 150.76$, df = 1, $p < 0.0001$ for the 1976 cohort; $\chi^2 = 88.37$, df = 1, $p < 0.0001$ for the 1978 cohort). In the previous analyses on time until first gopher attack, 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 these analyses, death from all causes was used as an endpoint. Therefore, mean survival times are slightly less than the mean times until gopher damage, but still show the same trends. The 1976 cohort had a mean survival time of 385 days (s.e. = 21 days) for the control unit and 1041 days (s.e. = 35 days) for the treated unit. The 1978 cohort had a mean survival time of 344 days (s.e. = 18 days) on the control unit and 630 days (s.e. = 18 days) on the treated unit.

Discussion

This study suggests that a reduction in gopher activity and an increase in survivorship of ponderosa pine seedlings can be achieved by atrazine treatments after clearing. Burton and Black (1978), in the area of our study, described above-ground parts of forbs as forming the largest component of the Mazama pocket gopher diet, followed by grasses. Succulent forbs were preferred to all other plants. Grasses were consumed most heavily during the dormant season when annual forbs were not available. Our atrazine treatments produced an altered habitat where most of these important

Table 3. Per cent of two cohorts of seedlings, 1976 and 1978 plantings, not receiving gopher damage on an atrazine herbicide treated unit and an untreated control unit

1976 Cohort Per cent without Gopher Damage:										
Months after planting:	3	5	8	12	17	25	27	33	38.5	51.5
Treated unit	98.5	98.5	95.8	91.5	88.2	67.6	67.0	57.8	51.3	33.8
Control unit	84.0	75.3	54.6	33.9	26.2	17.7	16.6	12.2	9.5	–[a]
1978 Cohort Per cent without Gopher Damage:										
Months after planting:	2	4.5	8	13.5	26.5					
Treated unit	99.0	98.5	94.1	86.6	62.5					
Control unit	94.0	84.3	46.0	35.0	28.8					

[a]The seedlings that remained after the last observation period were censored in this period

dietary elements were greatly diminished, so it is not surprising that their activity was greatly reduced on the treatment unit. It is especially noteworthy that the activity (and damage) remained suppressed at least 5 years beyond the initial treatment, and that only one maintenance treatment was applied in the intervening years. Lack of important food sources on the treatment unit appeared to inhibit re-invasion. Additional tests need to be conducted in areas where other species of pocket gopher occur, in other habitats where other species of tree seedlings are planted, and perhaps using a variety of chemicals or other methods for removing the preferred forage of pocket gophers to verify that the same effect can be achieved.

Acknowledgements

We are grateful to the personnel of the Chiloquin Ranger District, Winema National Forest for their cooperation and assistance during all phases of the study. The support and assistance of James Rochelle and Robert Anderson of the Weyerhaeuser Company was invaluable. We also are grateful to William E. Dusenberry, Craig Ramey and Michael W. Fall for their very helpful reviews of this paper. The Wayer-haeuser Company funded the first atrazine treatment and the U.S. Forest Service funded the operational planting of seedlings and provided seedlings for the second planting.

References

Acord, B. R. (1992) Responses of the ADC program to changing American society. *Proc. 15th Vert. Pest Conf.* (Ed. by J. E. Borrecco & R. E. Marsh) pp. 9–16, Univ. California, Davis

Anthony, R. M. and Barnes, V. G., Jr. (1984) Plot occupancy for indicating pocket gopher abundance and conifer damage. *Vertebrate Pest Control and Management Materials: Fourth Symposium*, ASTM STP 817 (Ed. by D. E. Kaukeinen), pp. 247–255, American Society for Testing and Materials, Philadelphia

Barnes, V. G., Jr. (1973) *Pocket gophers and reforestation in the Pacific Northwest: a problem analysis.* USDI Fish and Wildlife Service, Special Scientific Report – Wildlife No. 155, Washington, DC

Barnes, V. G., Jr. (1974) Response of pocket gopher populations to silvicultural practices in central Oregon. In *Wildlife and forest management in the Pacific Northwest* (Ed. by H. C. Black), pp. 167–175, Oregon State University

Black, H. C. and Hooven, E. (1977) Effects of herbicide-induced habitat changes on pocket gophers in southwestern Oregon. *29th Annual California Weed Conference*, pp. 119–127, Sacramento

Burton, D. H. and Black, H. C. (1978) Feeding habits of Mazama pocket gophers in south-central Oregon. *J. Wildl. Manage.* **42**, 383–390

Campbell, D. L., Farley, J. P., Hegdal, P. L., Engeman, R. M. and Krupa, H. W. (1992) Field efficacy evaluation of diphacinone paraffin bait blocks and strychnine oat groats for control of forest pocket gophers (*Thomomys* spp.). *Proc. 15th Vert. Pest Conf.* (Ed. by J. E. Borrecco and R. E. Marsh), pp. 299–302, Univ. California, Davis

Cristensen, M. D., Young, J. A. and Evans, R. A. (1974) Control of annual grasses and revegetation in the ponderosa pine woodlands. *J. Range Manage.* **27**, 143–145

Crouch, G. L. (1979) Atrazine improves survival and growth of ponderosa pine threatened by vegetative competition and pocket gophers. *Forest Sci.* **25**, 99–111

Crouch, G. L. and Franks, L. R. (1979) *Poisoning and trapping pocket gophers to protect conifers in northeastern Oregon.* USDA Forest Service Research Note, Pacific North West Forest and Range Experiment Station, Portland, OR, PNW-261

Crouch, G. L. and Hafenstein, E. (1977) *Atrazine promotes ponderosa pine regeneration.* USDA Forest Service Research Note, Pacific North West Forest and Range Experiment Station, Portland, OR, PNW-309

Daubenmire, R. (1959) A canopy-coverage method of vegetational analysis. *North West Sci.* **33**, 43–64

Hull, A. C., Jr. (1971) Effects of spraying with 2,4-D on abundance of pocket gophers in Franklin Basin, Idaho. *J. Range Manage.* **24**, 230–232

Kaplan, E. L. and Meier, P. (1958) Nonparametric estimation from incomplete observations. *J. Am. Stat. Assoc.* **53**, 457–481

Keith, J. O., Hansen, R. M. and Ward, A. L. (1959) Effect of 2,4-D on abundance and foods of pocket gophers. *J. Wildl. Manage.* **23**, 137–145

Volland, L. A. (1976) *Plant communities of the central Oregon pumice stone.* USDA For. Serv. Pac. Northwest Reg. R-6 Area Guide 4-2, 110 pp

Received 11 October 1994
Revised 28 December 1994
Accepted 28 December 1994